

Network Systems  
Science & Advanced  
Computing  
Biocomplexity Institute  
& Initiative  
University of Virginia

# Estimation of COVID-19 Impact in Virginia

June 30<sup>th</sup>, 2021

(data current to June 26<sup>th</sup> – 29<sup>th</sup>)

Biocomplexity Institute Technical report: TR 2021-075



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**BIOCOMPLEXITY** INSTITUTE

[biocomplexity.virginia.edu](https://biocomplexity.virginia.edu)

# About Us

- Biocomplexity Institute at the University of Virginia
  - Using big data and simulations to understand massively interactive systems and solve societal problems
- Over 20 years of crafting and analyzing infectious disease models
  - Pandemic response for Influenza, Ebola, Zika, and others



## Points of Contact

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# Overview

- **Goal:** Understand impact of COVID-19 mitigations in Virginia
- **Approach:**
  - Calibrate explanatory mechanistic model to observed cases
  - Project based on scenarios for next 4 months
  - Consider a range of possible mitigation effects in "what-if" scenarios
- **Outcomes:**
  - Ill, Confirmed, Hospitalized, ICU, Ventilated, Death
  - Geographic spread over time, case counts, healthcare burdens

# Key Takeaways

Projecting future cases precisely is impossible and unnecessary.

Even without perfect projections, we can confidently draw conclusions:

- **Case rates in Virginia have flattened with some minor growth in some areas**
- 63% of zip codes in Virginia (566 of 896 zips) had zero cases this past week; VA mean weekly incidence slightly up to 1.9/100K from 1.6/100K, US flat at 3.9/100K (from 4.2/100K)
- Vaccination rates continue to decline while measured acceptance among unvaccinated remains steady
- Projections show potential for growth, especially with variant Delta's increasing prevalence
- Recent updates:
  - Added Delta variant scenario as its growth becomes more predictable and expanded vaccination
  - Study scenarios: Fall resurgence and Fatigued control spike in summer
  - Limited waning of natural immunity included in fit and projections, also with seroprevalence update

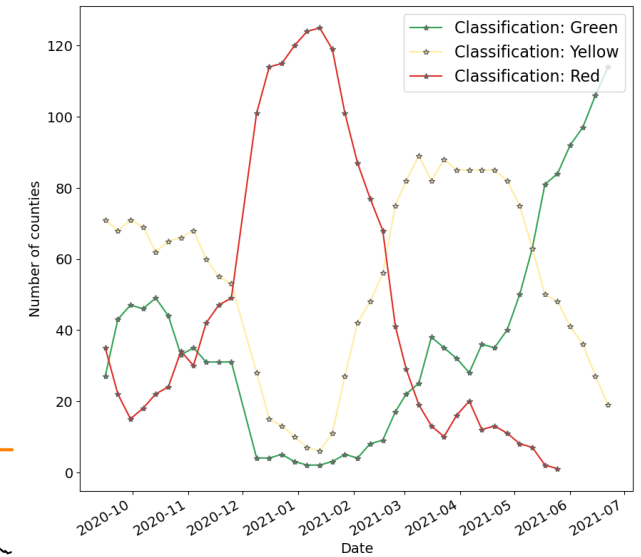
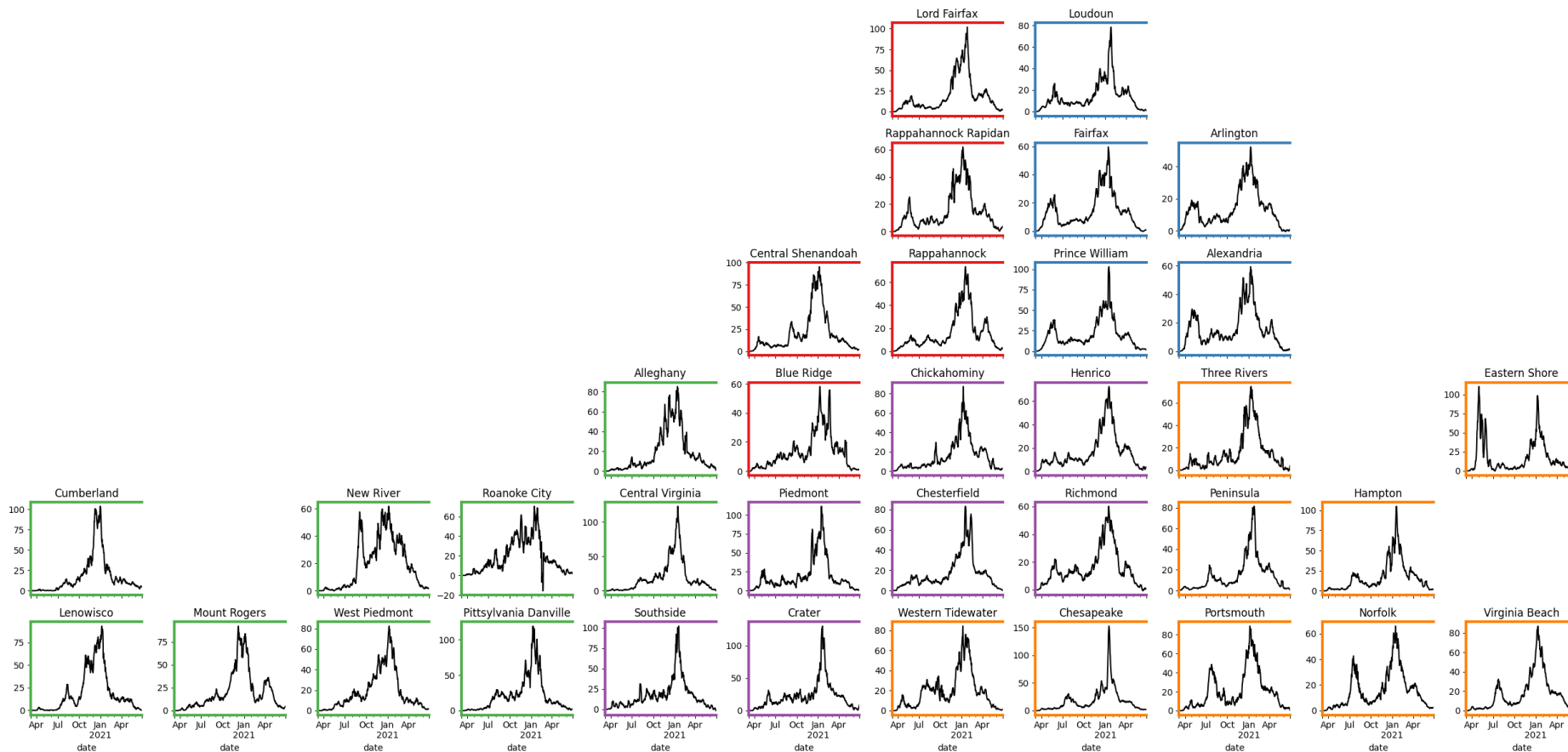
The situation continues to change. Models continue to be updated regularly.



# Situation Assessment

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# Case Rates (per 100k) and Test Positivity



<https://data.cms.gov/stories/s/q5r5-gjyu>

## County level test positivity from RT-PCR tests.

**Green:** <5.0%

(or with <20 tests in past 14 days)

**Yellow:** 5.0%-10.0%

(or with <500 tests and <2000 tests/100k and >10% positivity over 14 days)

**Red:** >10.0%

(and not "Green" or "Yellow")

# District Trajectories

**Goal:** Define epochs of a Health District's COVID-19 incidence to characterize the current trajectory

**Method:** Find recent peak and use hockey stick fit to find inflection point afterwards, then use this period's slope to define the trajectory

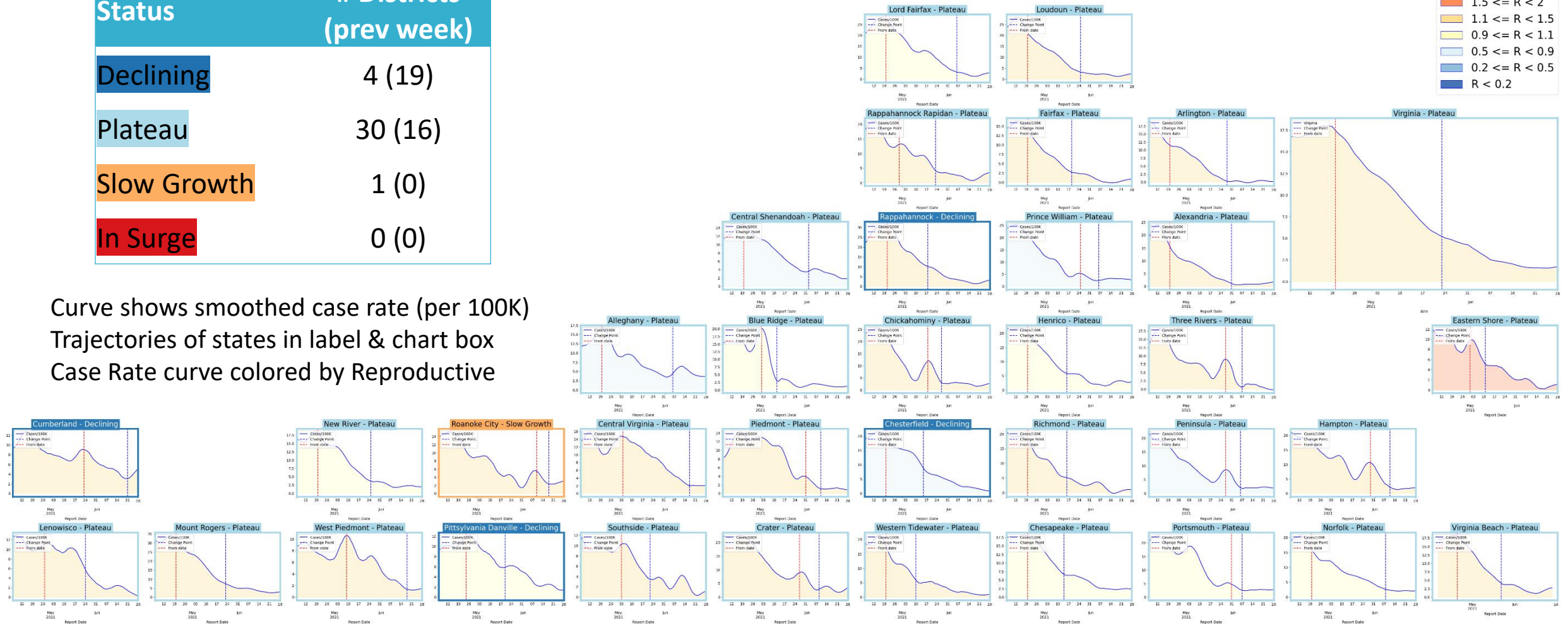


Trajectory	Description	Weekly Case Rate (per 100K) bounds	# Districts (prev week)
<b>Declining</b>	Sustained decreases following a recent peak	below -0.9	4 (19)
<b>Plateau</b>	Steady level with minimal trend up or down	above -0.9 and below 0.5	30 (16)
<b>Slow Growth</b>	Sustained growth not rapid enough to be considered a Surge	above 0.5 and below 2.5	1 (0)
<b>In Surge</b>	Currently experiencing sustained rapid and significant growth	2.5 or greater	0 (0)

# District Trajectories – last 10 weeks

Status	# Districts (prev week)
Declining	4 (19)
Plateau	30 (16)
Slow Growth	1 (0)
In Surge	0 (0)

Curve shows smoothed case rate (per 100K)  
Trajectories of states in label & chart box  
Case Rate curve colored by Reproductive



# Estimating Daily Reproductive Number

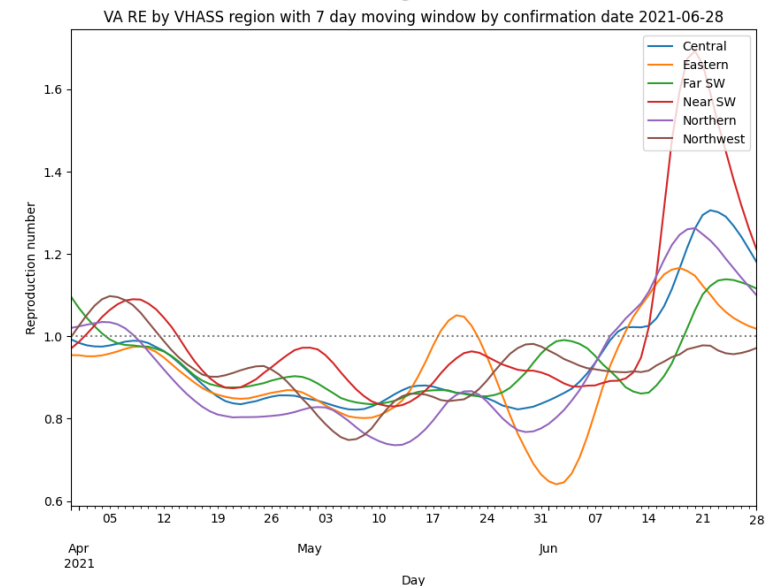
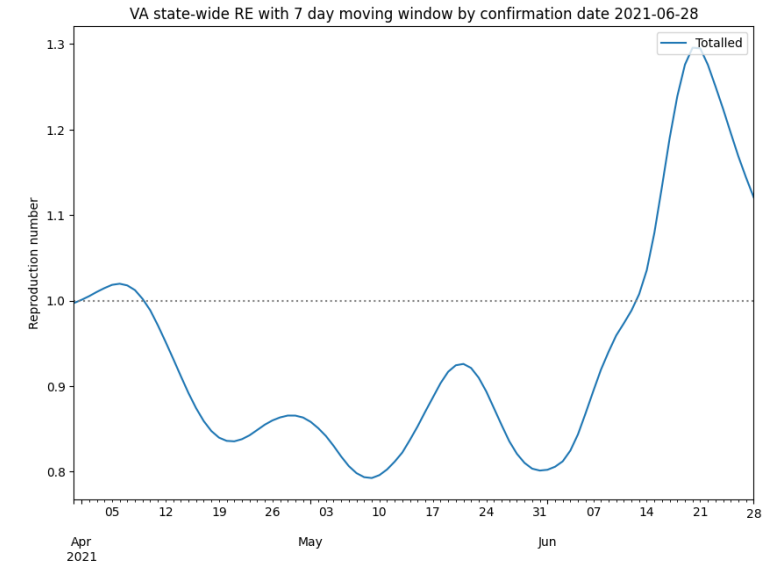
## June 28<sup>th</sup> Estimates

Region	Date Confirmed $R_e$	Date Confirmed Diff Last Week
State-wide	1.121	0.235
Central	1.180	0.289
Eastern	1.018	-0.007
Far SW	1.116	0.305
Near SW	1.211	0.413
Northern	1.100	0.176
Northwest	0.972	0.091

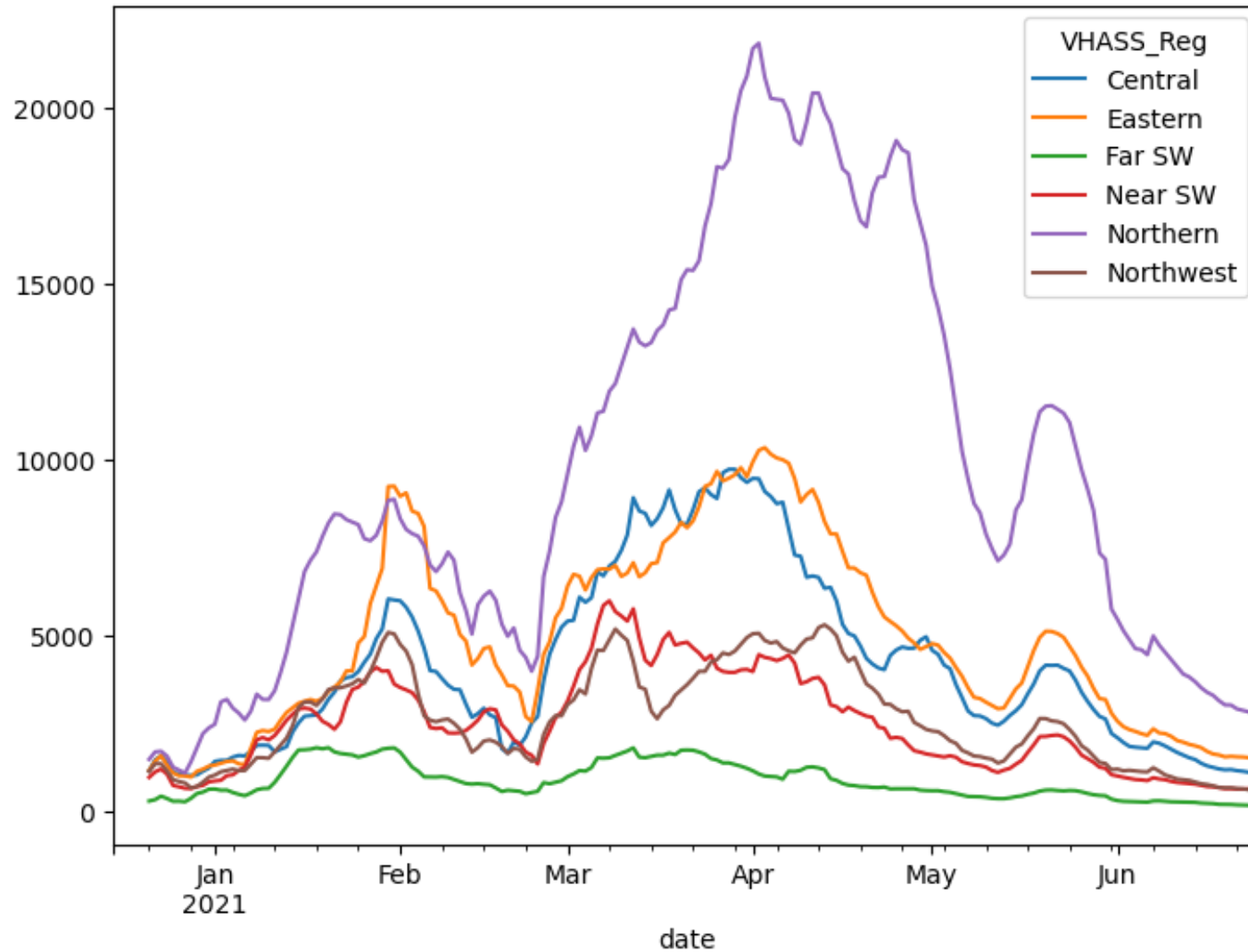
### Methodology

- Wallinga-Teunis method (EpiEstim<sup>1</sup>) for cases by confirmation date
- Serial interval: updated to discrete distribution from observations (mean=4.3, Flaxman et al, Nature 2020)
- Using Confirmation date since due to increasingly unstable estimates from onset date due to backfill

1. Anne Cori, Neil M. Ferguson, Christophe Fraser, Simon Cauchemez. A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics. American Journal of Epidemiology, Volume 178, Issue 9, 1 November 2013, Pages 1505–1512, <https://doi.org/10.1093/aje/kwt133>

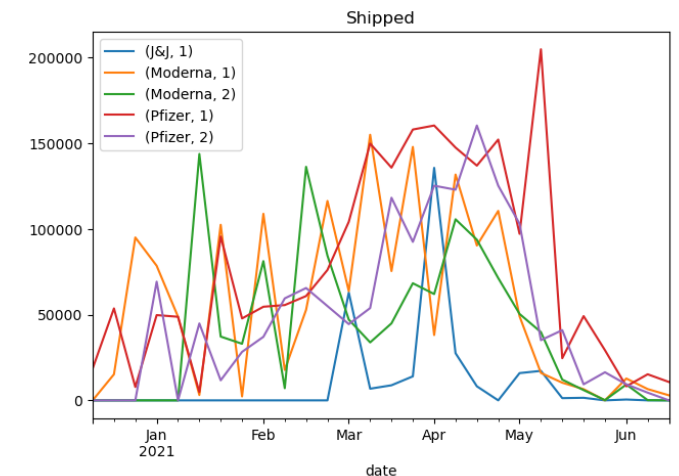


# Vaccination Administration Slows



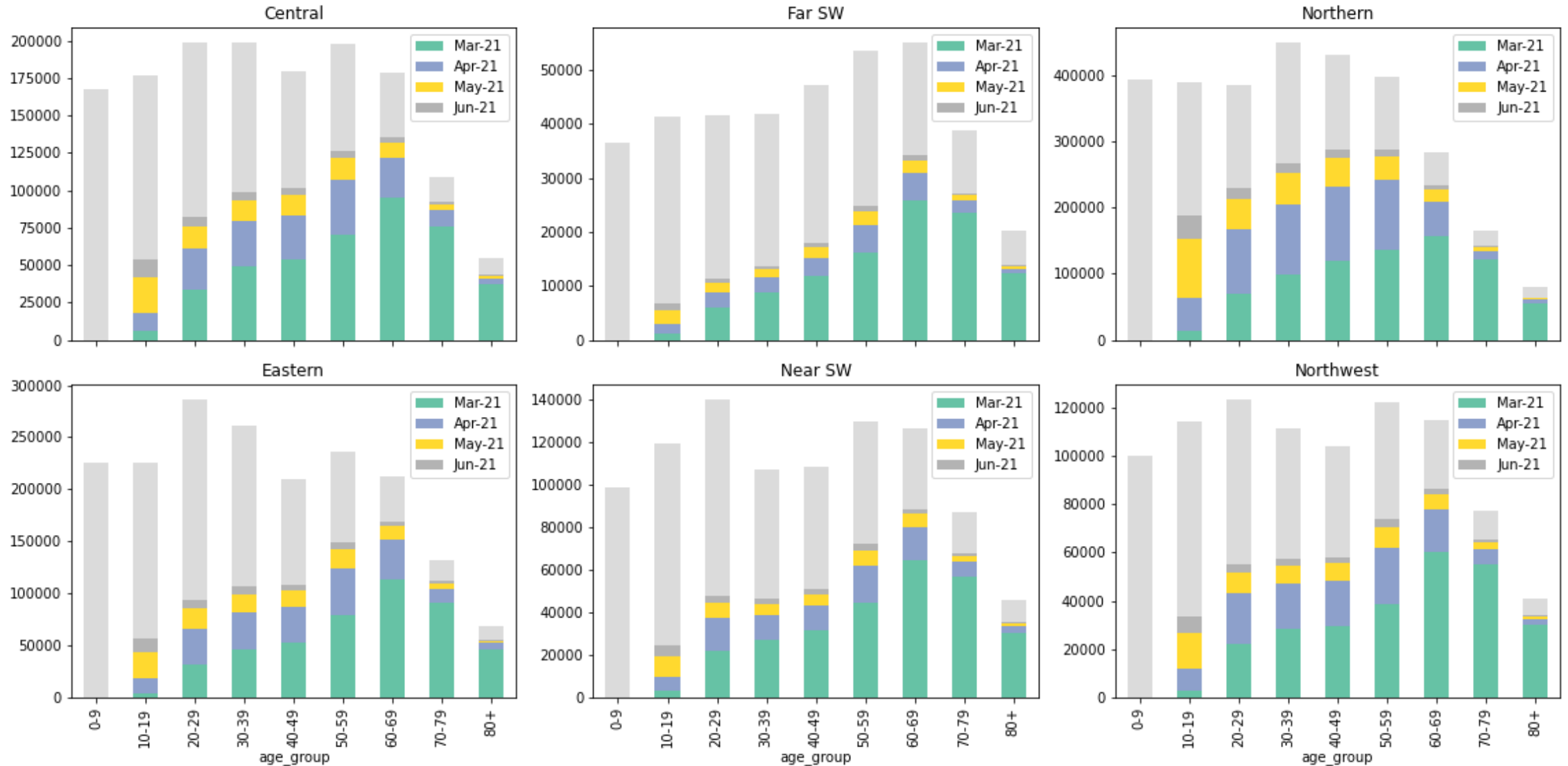
## Regional Vaccine courses initiated per day:

- Total counts of first dose of vaccines across regions



Shipments have slowed with decreased demand

# Vaccinations Shift to Younger Populations



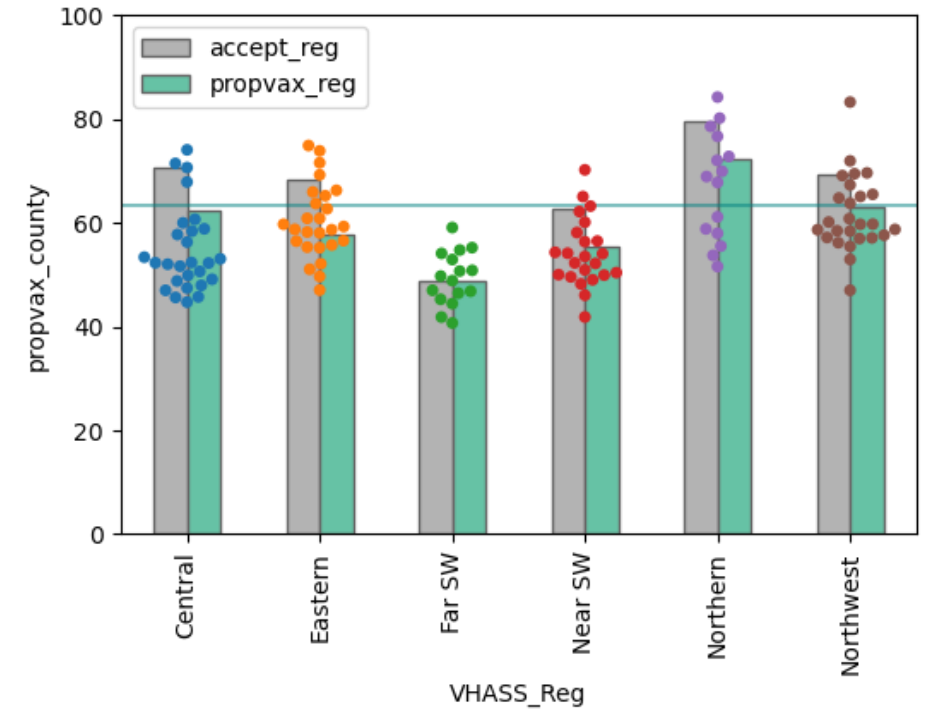


# Vaccination Acceptance by Region

## Corrections to surveys:

- Facebook administered survey is timely and broad, but biased by who accesses Facebook and answers the survey
- Correction approach:
  - Calculate an over-reporting fraction based on reported vaccinations compared to VDH administration data
  - Cross-validate coarse corrections against HPS survey at the state level and corrected in same manner

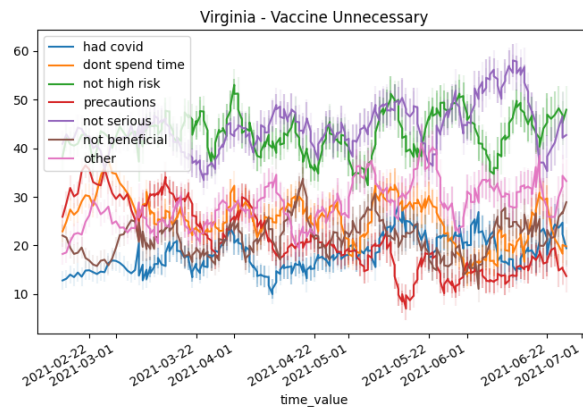
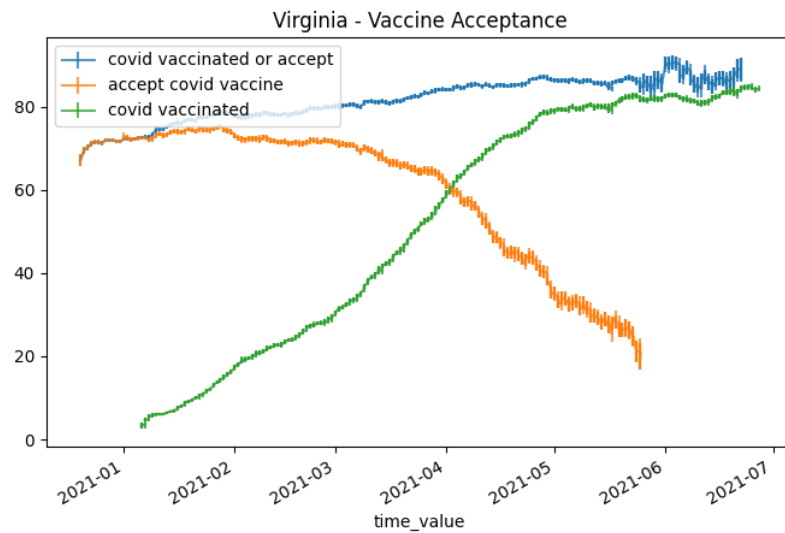
Region	COVIDcast accepting corrected	VDH proportion vaccinated
Central	72%	62%
Eastern	67%	57%
Far SW	49%	48%
Near SW	63%	55%
Northern	79%	72%
Northwest	69%	62%
<b>Virginia</b>	<b>72%</b>	<b>63%</b>



**Grey Bar:** Survey measured and corrected acceptance  
**Green Bar:** Proportion of eligible population administered a vaccine  
**Dots:** Proportion administered at least one dose for each county

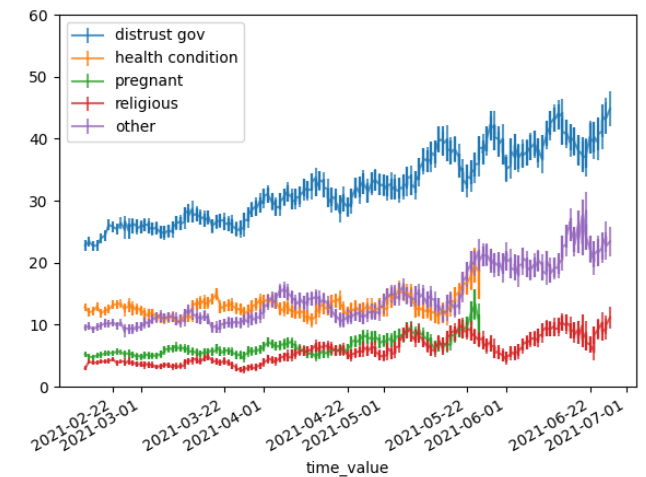
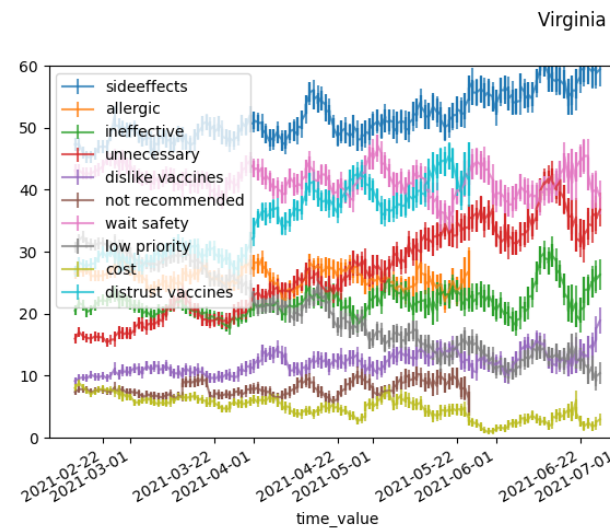


# Vaccine Acceptance in Virginia - COVIDcast



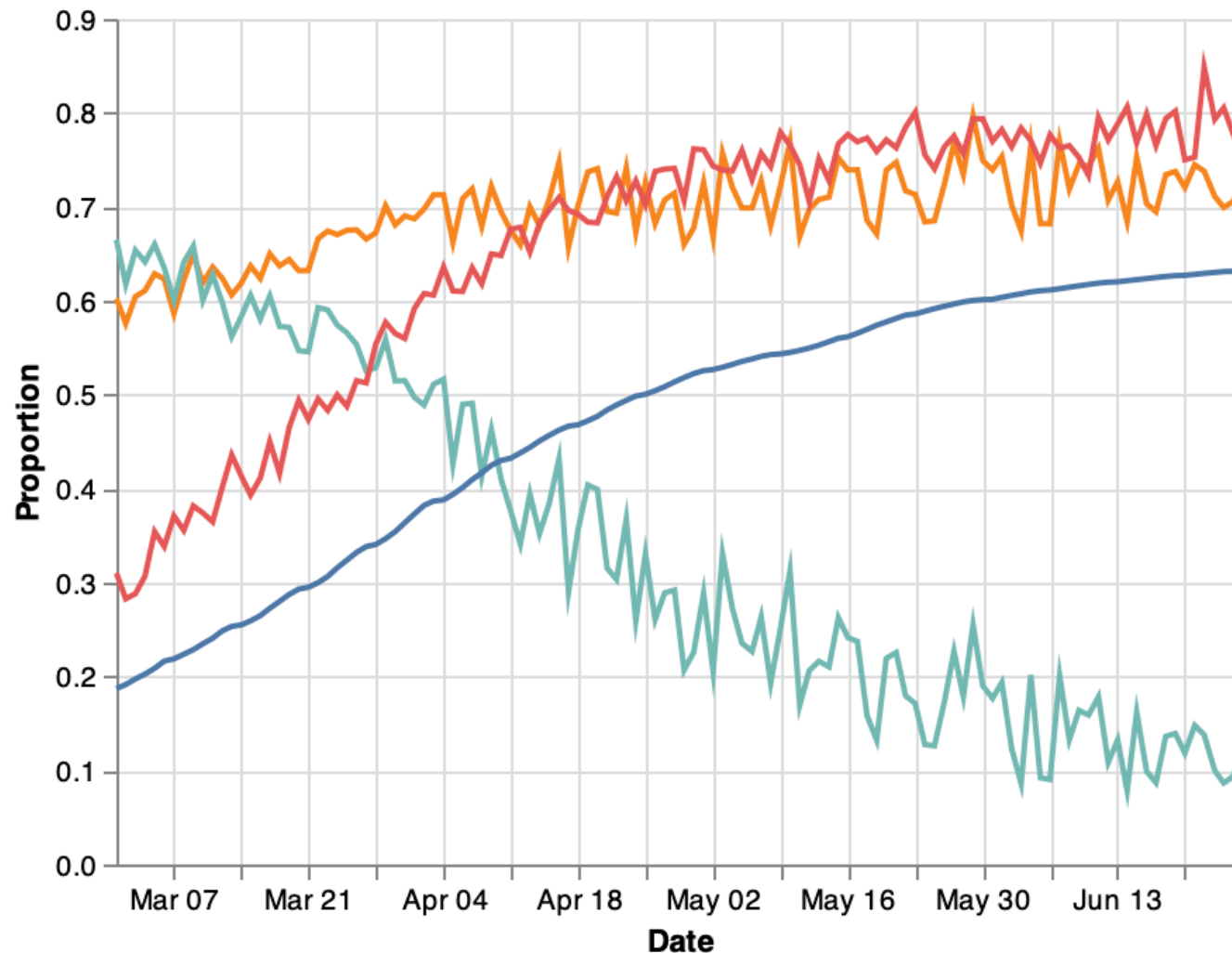
## Acceptance remains high:

- Proportion of Virginians that have already or would definitely or probably accept vaccination if offered today
- *Survey respondents are reporting high levels of vaccination of ~80% reflecting bias of the mechanism*
- **Top reasons for hesitancy:** side effects, distrust (increasing), unnecessary (increasing)
- **More likely to take if recommended by:** doctors and friends
- **Reasons unnecessary:** Not serious, not high risk, or other



Data Source: <https://covidcast.cmu.edu>

# Vaccine Acceptance Components over Time



## variable

- Administered Vaccines
- Corrected Acceptance
- Surveyed Vaccinated
- Unvaccinated Acceptance

## Vaccine Acceptance has risen as vaccination rates have climbed

- Corrected Acceptance reflects the daily measured overall acceptance
- Unvaccinated Acceptance shows still ~10% of those who are unvaccinated are definitely or probably willing to be vaccinated
- Unvax acceptance has declined a bit and leveled off in last couple of weeks, final 10% may be waiting for FDA approval

Data Source: <https://covidcast.cmu.edu>

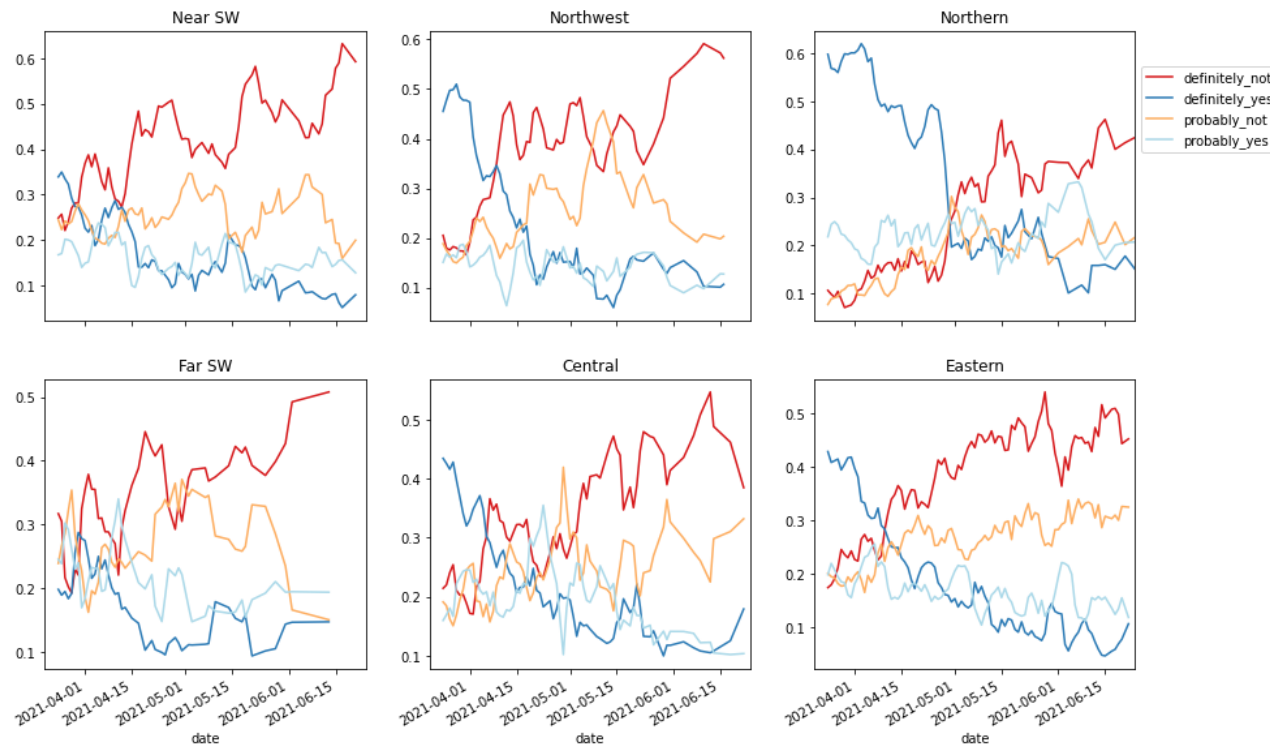
30-Jun-21

# Vaccine Acceptance by Region- COVIDcast

## Levels of Acceptance and potential acceptance in flux:

- Nearly all the “Definitely Yes” have been vaccinated, yet there are 10-15% remaining across the regions
- Northwest and Southwest (to lesser degree) see growth in “probably not”, seemingly from “definitely not”

### Unvaccinated Only



### All Respondents



Data Source: <https://covidcast.cmu.edu>

30-Jun-21

# SARS-CoV2 Variants of Concern

## Emerging new variants will alter the future trajectories of pandemic and have implications for future control

- Emerging variants can:
  - Increase transmissibility
  - Increase severity (more hospitalizations and/or deaths)
  - Limit immunity provided by prior infection and vaccinations
- Genomic surveillance remains very limited
  - Challenges ability to estimate impact in US to date and estimation of arrival and potential impact in future

	New WHO Name	Transmissibility	Immune Evasiveness	Vaccine Effectiveness <sup>^</sup>
Ancestral		—	—	✓
D614G		+	—	✓
B.1.1.7	Alpha	+++	—	✓
B.1.351	Beta	+	++++	✓
P.1	Gamma	++	++	✓
B.1.429	Epsilon	+	+	✓
B.1.526	Iota	+	+	✓
B.1.617.2	Delta	++++*	++ <sup>#</sup>	✓

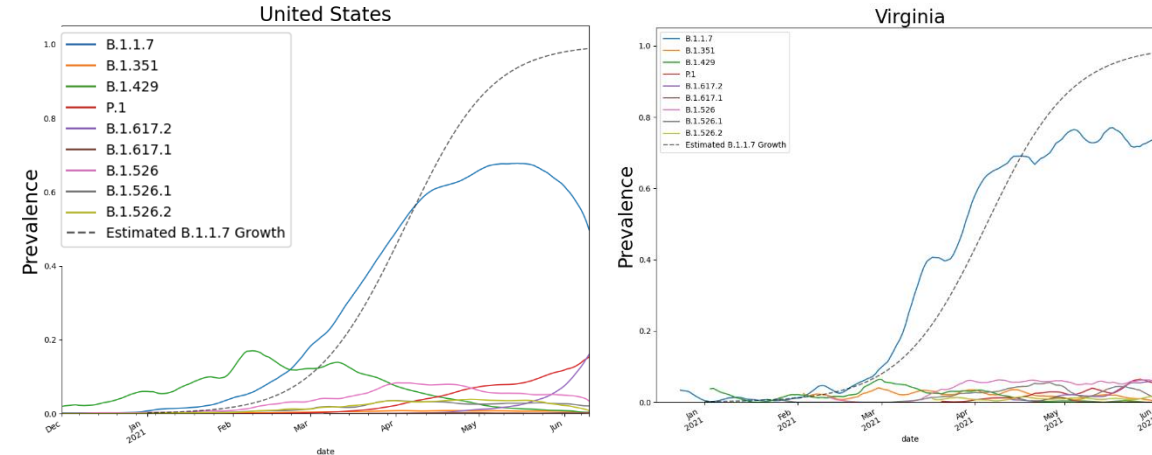
<sup>\*</sup>Relative transmissibility to B.1.1.7 yet to be fully defined

<sup>^</sup>Effectiveness from real world evidence vs. severe illness, not all vaccines are effective vs all variants, and importance of 2-doses, especially for B.1.617.2 for which 1 dose of mRNA or AZ is only ~30% effective <sup>#</sup> May carry more immune escape than P.1, to be determined



World Health Organization

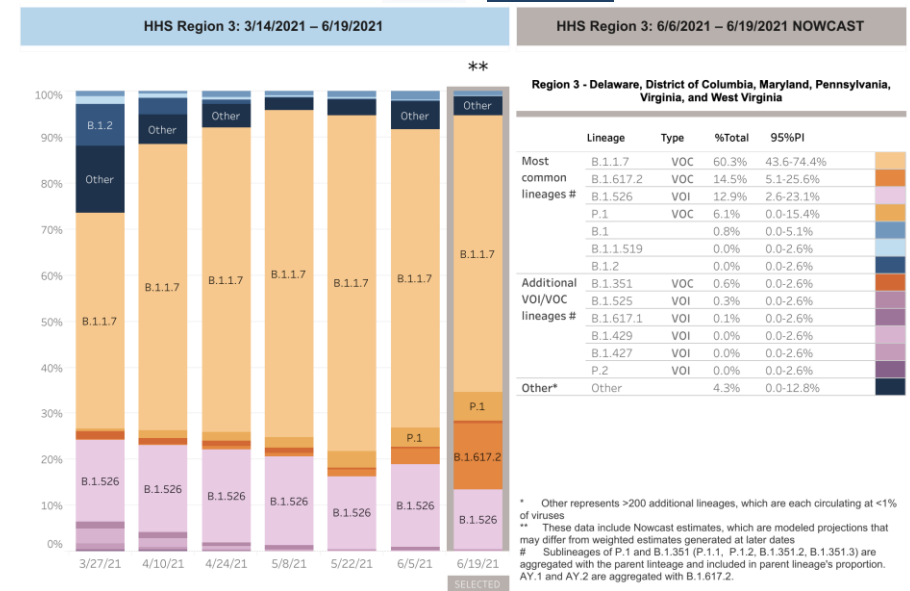
WHO and Eric Topol



GISAID

outbreak.info

Outbreak Info



\* Other represents >200 additional lineages, which are each circulating at <1% of viruses  
<sup>\*\*</sup> These data include Nowcast estimates, which are modeled projections that may differ from weighted estimates generated at later dates  
<sup>#</sup> Sublineages of P.1 and B.1.351 (P.1.1, P.1.2, B.1.351.2, B.1.351.3) are aggregated with the parent lineage and included in parent lineage's proportion. AY.1 and AY.2 are aggregated with B.1.617.2.

Collection date, two weeks ending



CDC Variant Tracking

# SARS-CoV2 Variants of Concern

## Alpha $\alpha$ - Lineage B.1.1.7

**Prevalence:** Levels have stalled and are now dropping in most states; flat in VA

**Transmissibility:** Estimated increase of 50% compared to previous variants. B.1.1.7's mutations boost its overall levels of viremia; [study from Public Health England](#) shows contacts of B.1.1.7 cases are more likely (50%) to test positive

**Severity:** Increased risk of hospitalization (60%) and mortality (60%). [Danish](#) study shows B.1.1.7 to have a 64% higher risk of hospitalization, while [Public Health Scotland](#) studies showed a range of 40% to 60%; [Study in Nature](#) estimates 60% higher mortality

## Beta $\beta$ - Lineage B.1.351

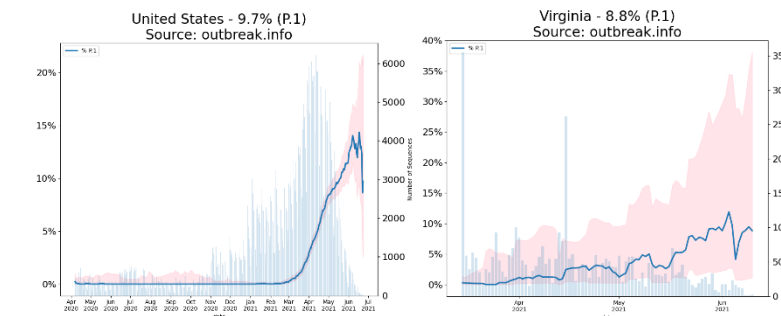
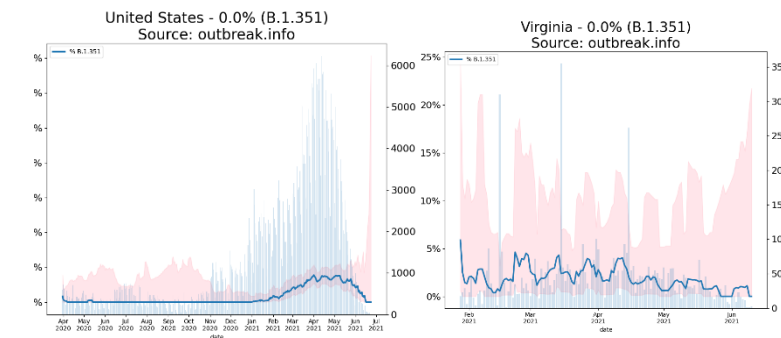
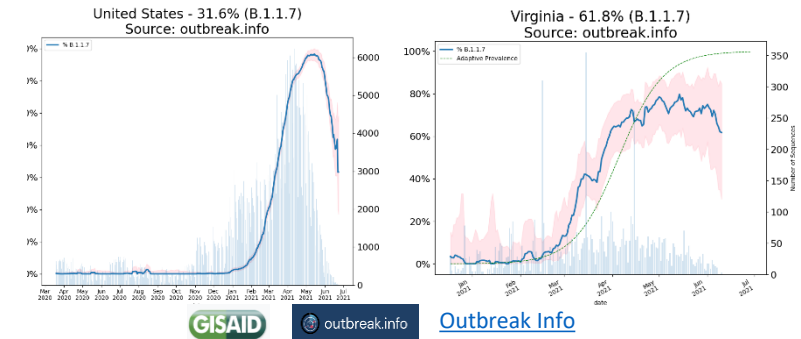
**Prevalence:** Levels have remained low, as this variant's transmissibility can't compete with B.1.1.7, however, as more of the population becomes immune it may gain an advantage

**Immune Escape:** Many studies show that convalescent sera from previously infected individuals does not neutralize B.1.351 virus well which is [predictive](#) of [protection](#), however, [vaccine induced immunity](#) shows [signs](#) of [effectiveness](#)

## Gamma $\gamma$ - Lineage P.1

**Prevalence:** Nationally at 10%, slow increase in VA at 9%

[Study](#) estimates 17-32% of all infections in Manaus in 2021 were reinfections, which helps explain [data from Brazil](#) demonstrating P.1's continued dominance in Rio despite presence of B.1.1.7





# SARS-CoV2 Variants of Concern

## Delta $\delta$ - Lineage B.1.617.2 and related subvariants

- Delta plus  $\delta+$  lineage which contains the K417N mutation is emerging as a sub-variant that is even more transmissible. Declared a VoC in India
- Strain shows [continued growth in Europe](#) and across US, predicted to predominate in coming weeks (July 2<sup>nd</sup> in VA), Scotland now experiencing highest daily case counts, driven by delta.
- [Several studies](#) estimate B.1.617.2 to have 100% faster growth than B.1.1.7, and a UK study suggests a 13% advantage over B.1.1.7; we are roughly tracking what seems to be a ~60% growth rate advantage in VA
- [More studies](#) show limited [immune escape](#) similar to B.1.351, however, many studies still suggest protection remains for vaccinated, especially 2 doses and mRNA vaccines
- [PHE study](#) shows limited efficacy of Astra-Zeneca with only one dose, efficacy returns following 2<sup>nd</sup> dose, [also stronger with a followup Pfizer](#)
- [Public Health Scotland study in Lancet](#) suggests Delta is 2x more likely to cause hospitalization than Alpha
- [New study](#) shows evasion of natural and of Pfizer vax (though weak) also shows transmissibility boost comes from more efficient fusion and lung cell entry

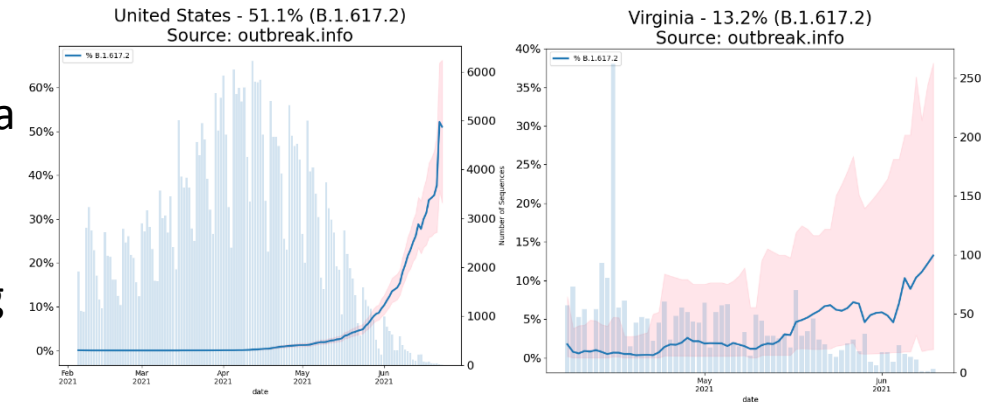
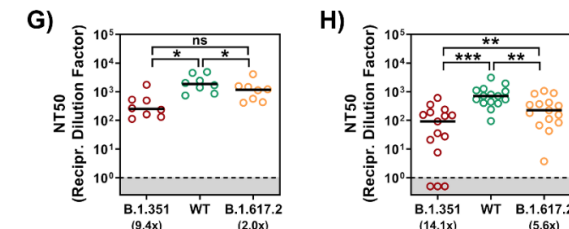


Table 1: Estimated vaccine effectiveness against hospitalisation

Vaccination status	Alpha			Delta		
	OR vs symptomatic disease	HR vs hospitalisation	VE vs hospitalisation	OR vs symptomatic disease	HR vs hospitalisation	VE vs hospitalisation
Any vaccine						
Dose 1	0.51 (0.48-0.55)	0.44 (0.28-0.70)	78% (65-86)	0.69 (0.64-0.75)	0.37 (0.22-0.63)	75% (57-85)
Dose 2	0.13 (0.1-0.15)	0.64 (0.24-1.72)	92% (78-97)	0.20 (0.18-0.23)	0.29 (0.11-0.72)	94% (85-98)
Pfizer						
Dose 1	0.53 (0.47-0.58)	0.32 (0.14-0.73)	83% (62-93)	0.64 (0.54-0.77)	0.10 (0.01-0.76)	94% (46-99)
Dose 2	0.06 (0.05-0.08)	0.88 (0.21-3.77)	95% (78-99)	0.12 (0.1-0.15)	0.34 (0.10-1.18)	96% (86-99)
AstraZeneca						
Dose 1	0.51 (0.48-0.55)	0.48 (0.30-0.77)	76% (61-85)	0.70 (0.65-0.76)	0.41 (0.24-0.70)	71% (51-83)
Dose 2	0.26 (0.21-0.32)	0.53 (0.15-1.80)	86% (53-96)	0.33 (0.28-0.39)	0.25 (0.08-0.78)	92% (75-97)

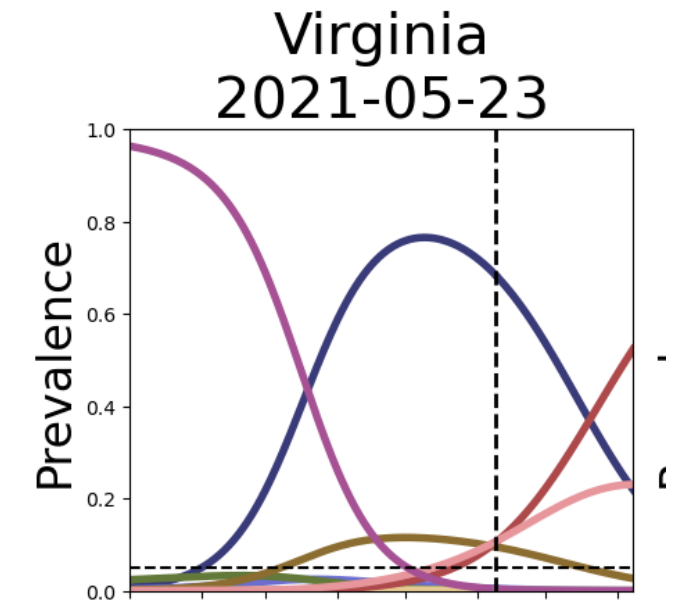
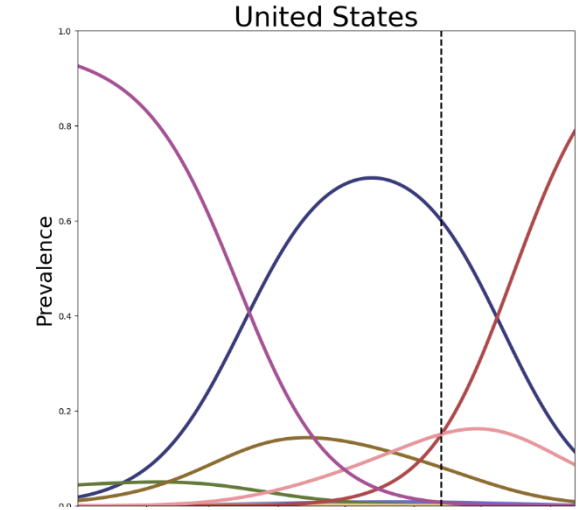
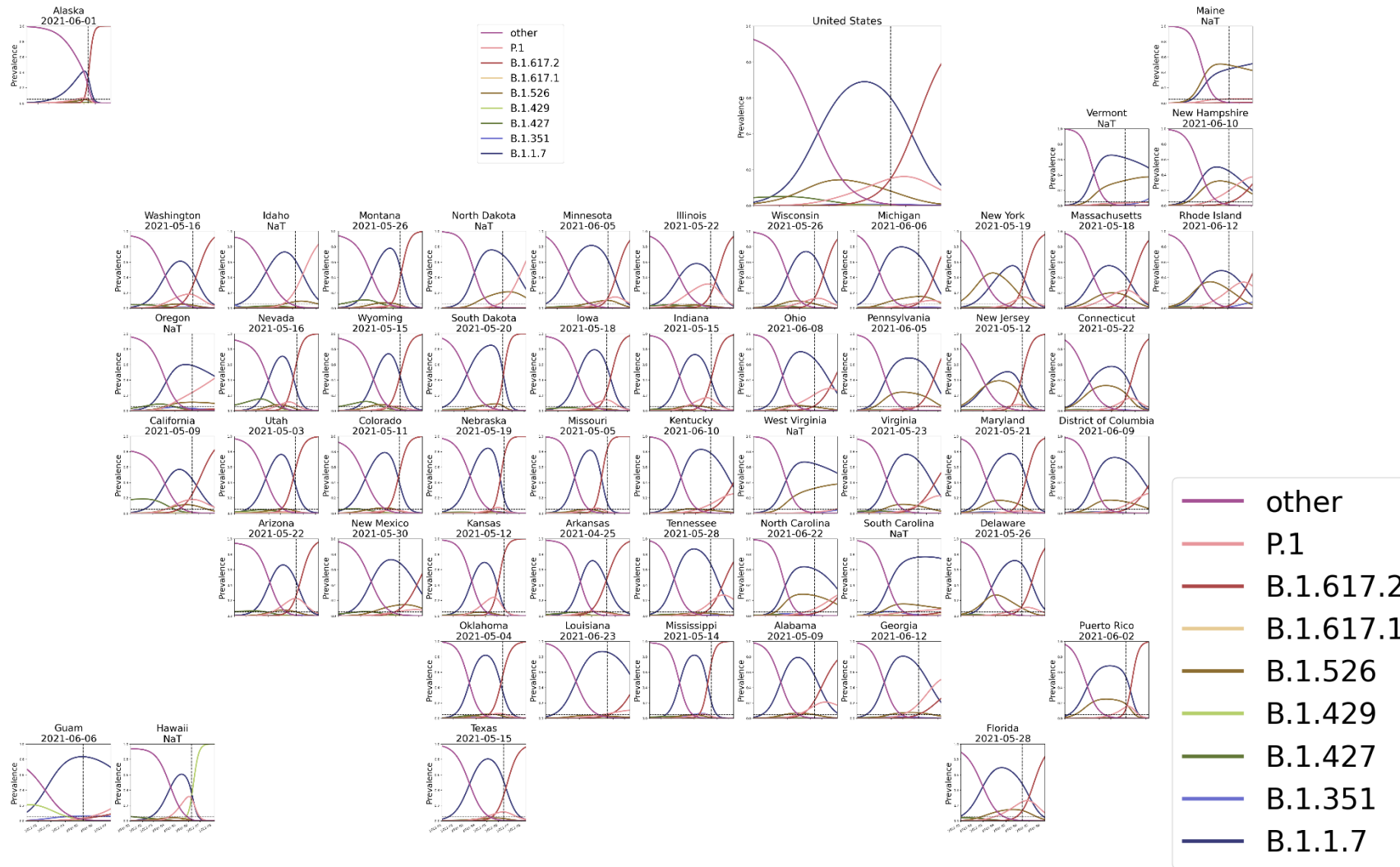
Public Health England study shows vaccines are effective against hospitalization with Delta variant infections (94-96% for Pfizer). Also shows that one dose AZ has much lower efficacy (71%) [PHE](#)



We show,, that B.1.617.2 evades control by antibodies induced upon infection and and even Pfizer's vaccine, although with lower efficiency as compared to B.1.351, as well as a common monoclonal treatment. Finally, we show increased Calu-3 lung cell entry and enhanced cell-to-cell fusion of B.1.617.2, which may contribute to augmented transmissibility and pathogenicity of this variant.

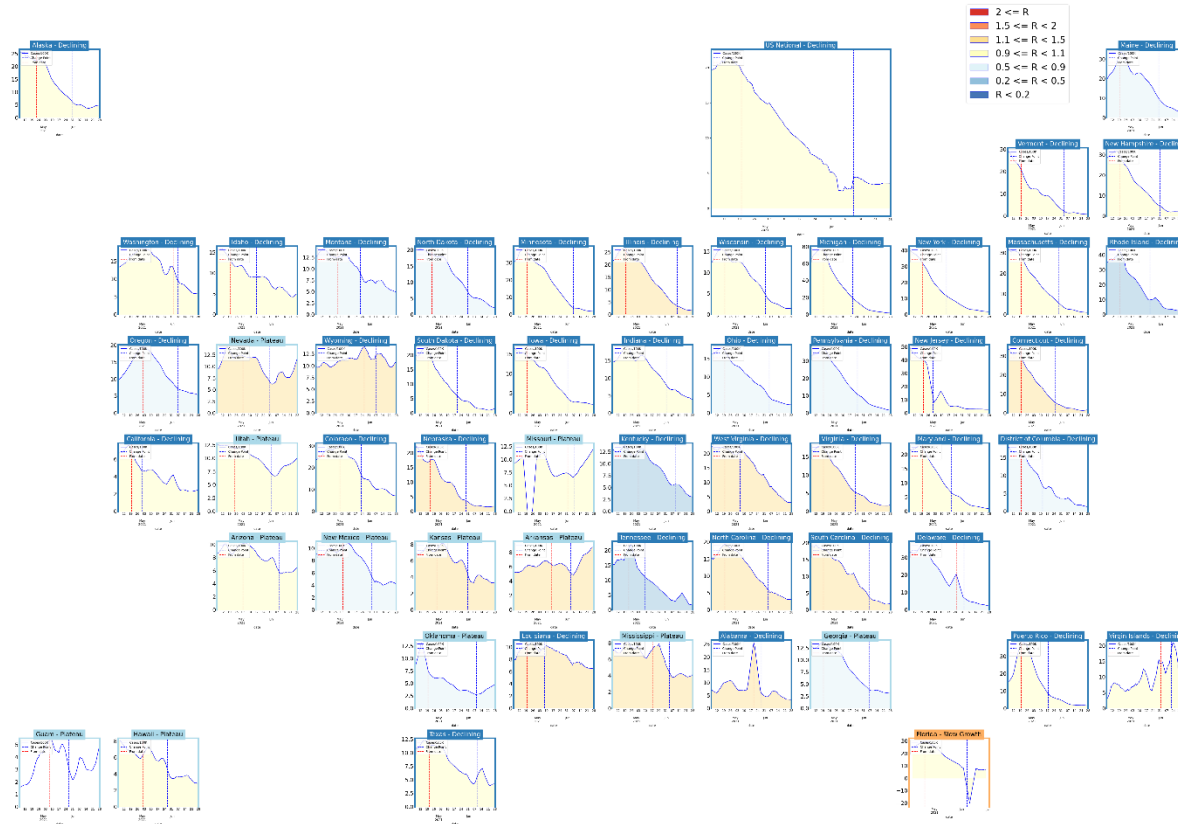
[BioRxiv](#)

# Variant of Concern Trajectories



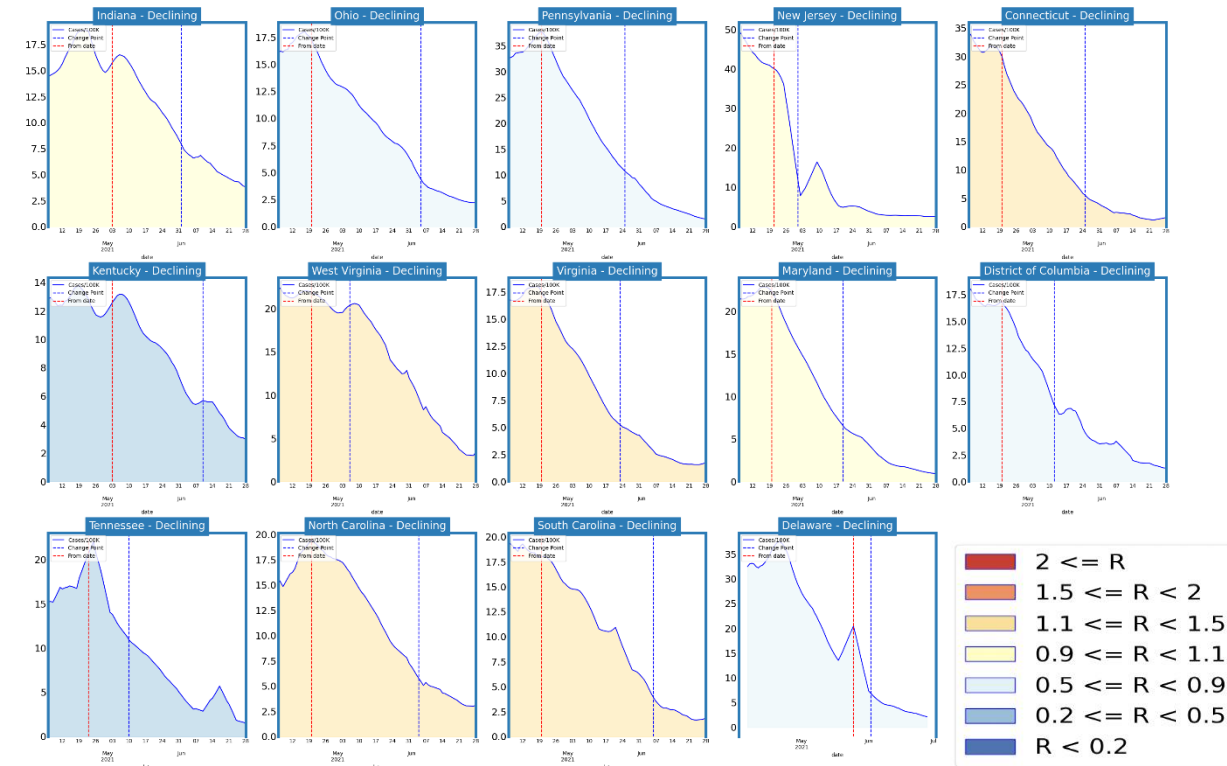
# Other State Comparisons

## Trajectories of States



- Nearly all states are declining
- Some states, most with low vaccination rates or high Delta, show some rebounds

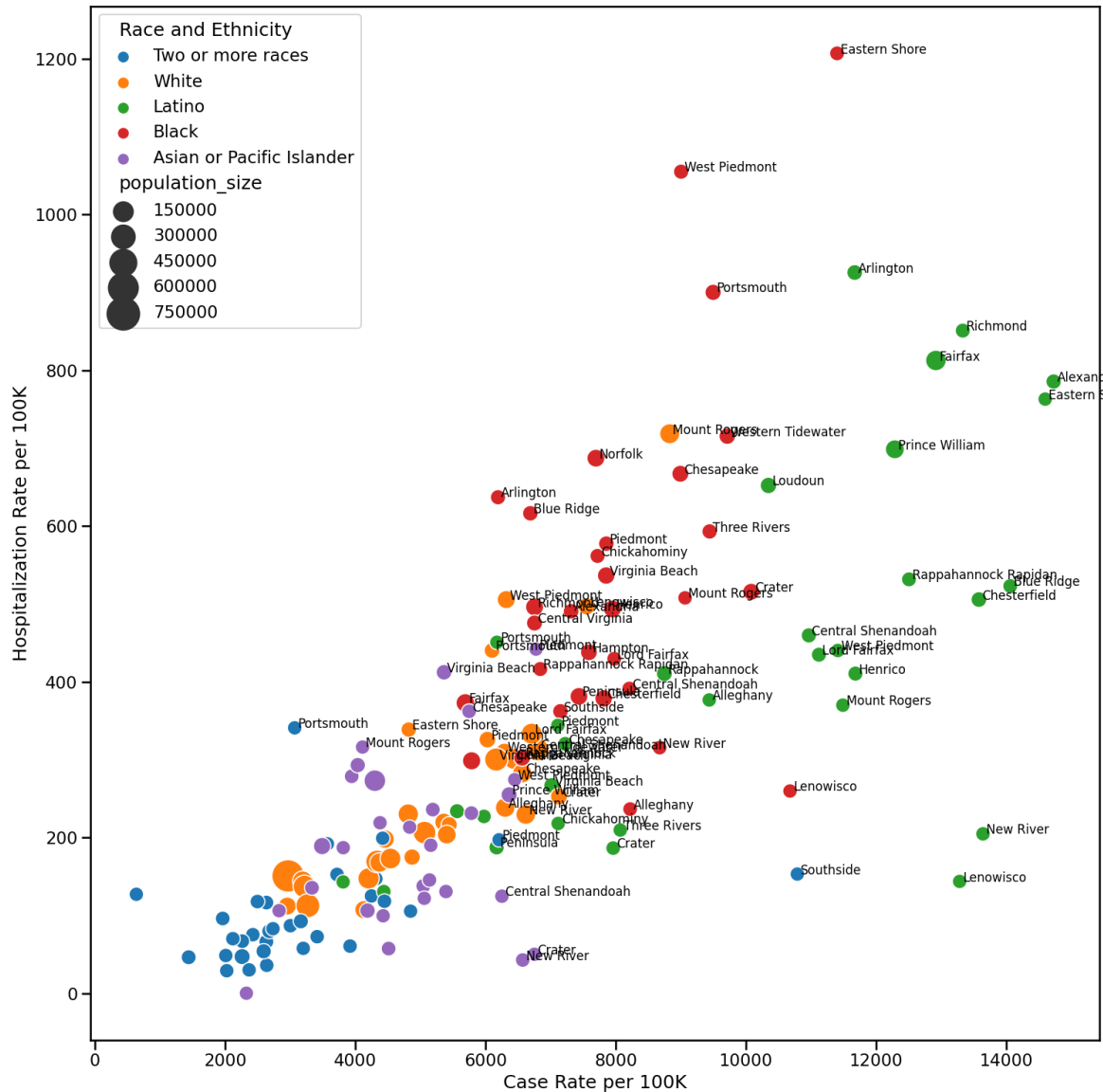
## Virginia and her neighbors



- VA and neighbors are all declining with steady pace
- All neighbors are now well below 10/100K level



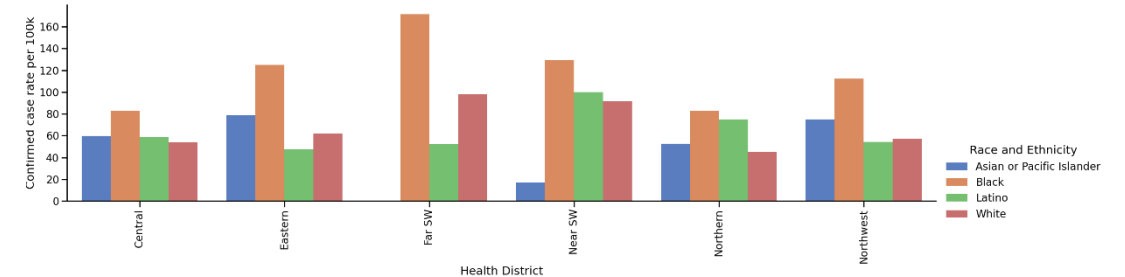
# Race and Ethnicity cases per 100K



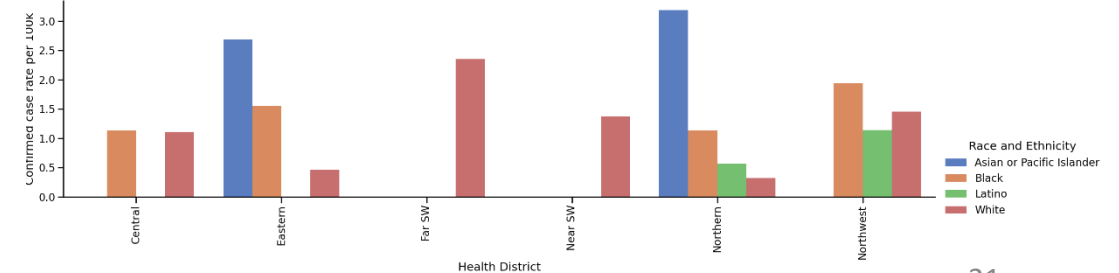
## Rates per 100K of each Racial-Ethnic population

- Each Health District's Racial-Ethnic population is plotted by their Hospitalization and Case Rate
- Points are sized based on their overall population size (overlapping labels removed)
- Change in rates over the last 2 weeks

## Case Rate Change in last 14 days



## Death Rate Change in last 14 days

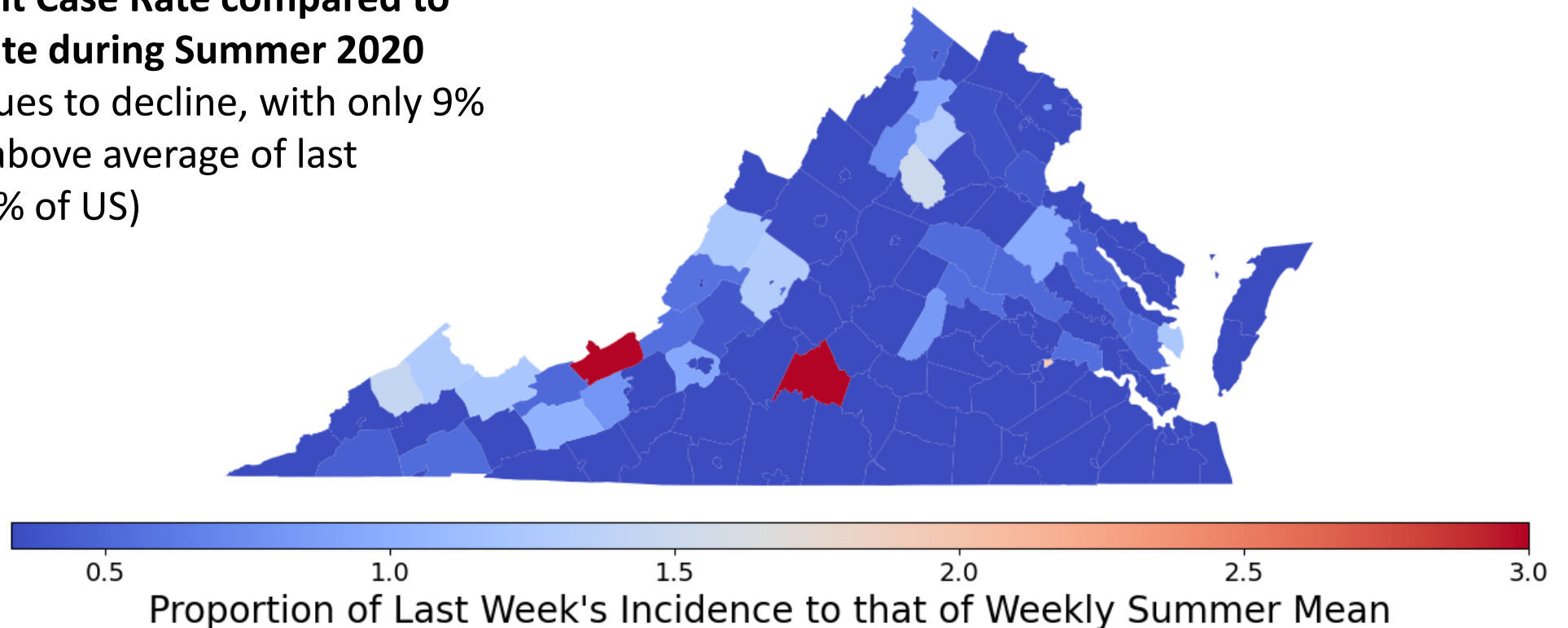


# Recent Incidence Compared to Summer 2020

Recent Incidence Compared to Weekly Summer Mean by County  
Mean: 0.4; Median: 0.15; IQR: 0.06-0.42

## Ratio of Recent Case Rate compared to mean Case Rate during Summer 2020

- Ratio continues to decline, with only 9% of counties above average of last summer (17% of US)



# Zip code level weekly Case Rate (per 100K)

## Case Rates in the last week by zip code

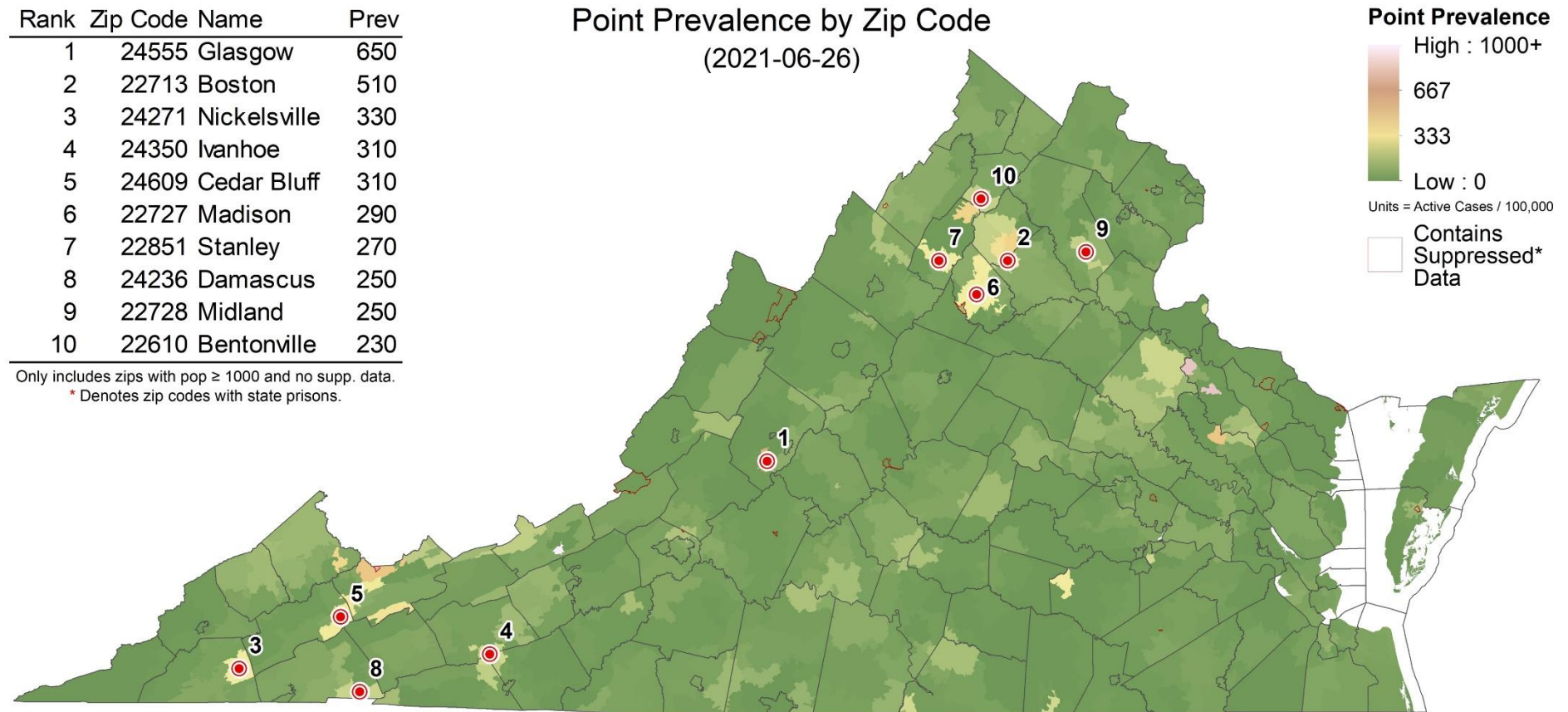
- Adjusted Color gradient to lower rates, thus red is a lower prevalence
- Some counts are low and suppressed to protect anonymity, those are shown in white

Rank	Zip Code	Name	Prev
1	24555	Glasgow	650
2	22713	Boston	510
3	24271	Nickelsville	330
4	24350	Ivanhoe	310
5	24609	Cedar Bluff	310
6	22727	Madison	290
7	22851	Stanley	270
8	24236	Damascus	250
9	22728	Midland	250
10	22610	Bentonville	230

Only includes zips with pop ≥ 1000 and no supp. data.

\* Denotes zip codes with state prisons.

Point Prevalence by Zip Code  
(2021-06-26)

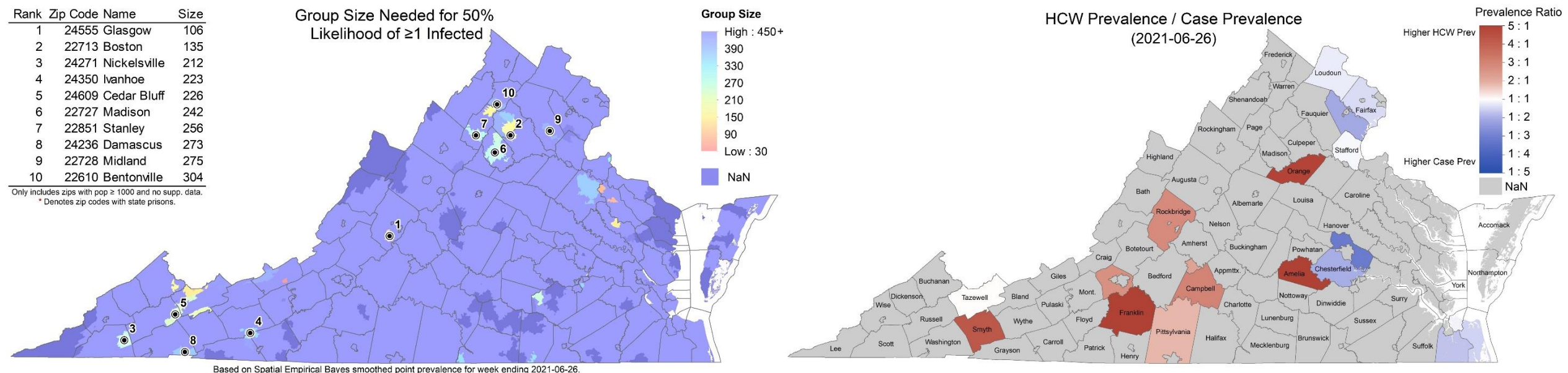


Based on Spatial Empirical Bayes smoothed point prevalence for week ending 2021-06-26.

# Risk of Exposure by Group Size and HCW prevalence

## Case Prevalence in the last week by zip code used to calculate risk of encountering someone infected in a gathering of randomly selected people (group size 25)

- **Group Size:** Assumes 2 undetected infections per confirmed case (ascertainment rate from recent seroprevalence survey), and shows minimum size of a group with a 50% chance an individual is infected by zip code (eg in a group of 106 in Glasgow, there is a 50% chance someone will be infected)
- **HCW prevalence:** Case rate among health care workers (HCW) in the last week using patient facing health care workers as the denominator



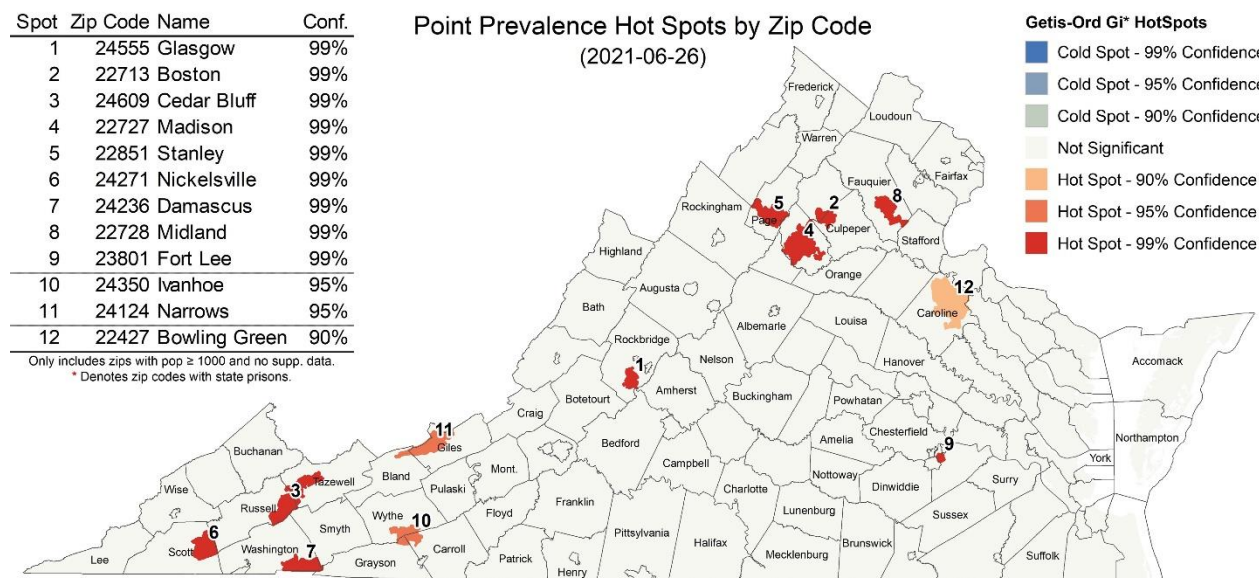


# Current Hot-Spots

## Case rates that are significantly different from neighboring areas or model projections

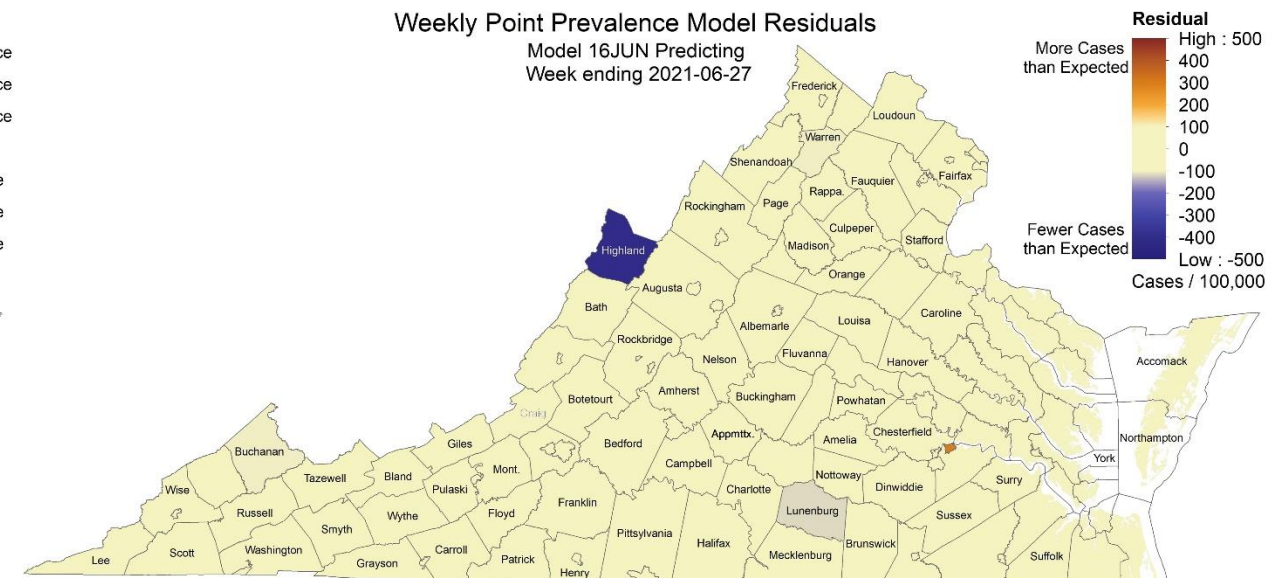
- **Spatial:** SaTScan based hot spots compare clusters of zip codes with weekly case prevalence higher than nearby zip codes to identify larger areas with statistically significant deviations
- **Temporal:** The weekly case rate (per 100K) projected last week compared to observed by county, which highlights temporal fluctuations that differ from the model's projections

### Spatial Hotspots



Based on Global Empirical Bayes smoothed point prevalence for week ending 2021-06-26.

### Clustered Temporal Hotspots

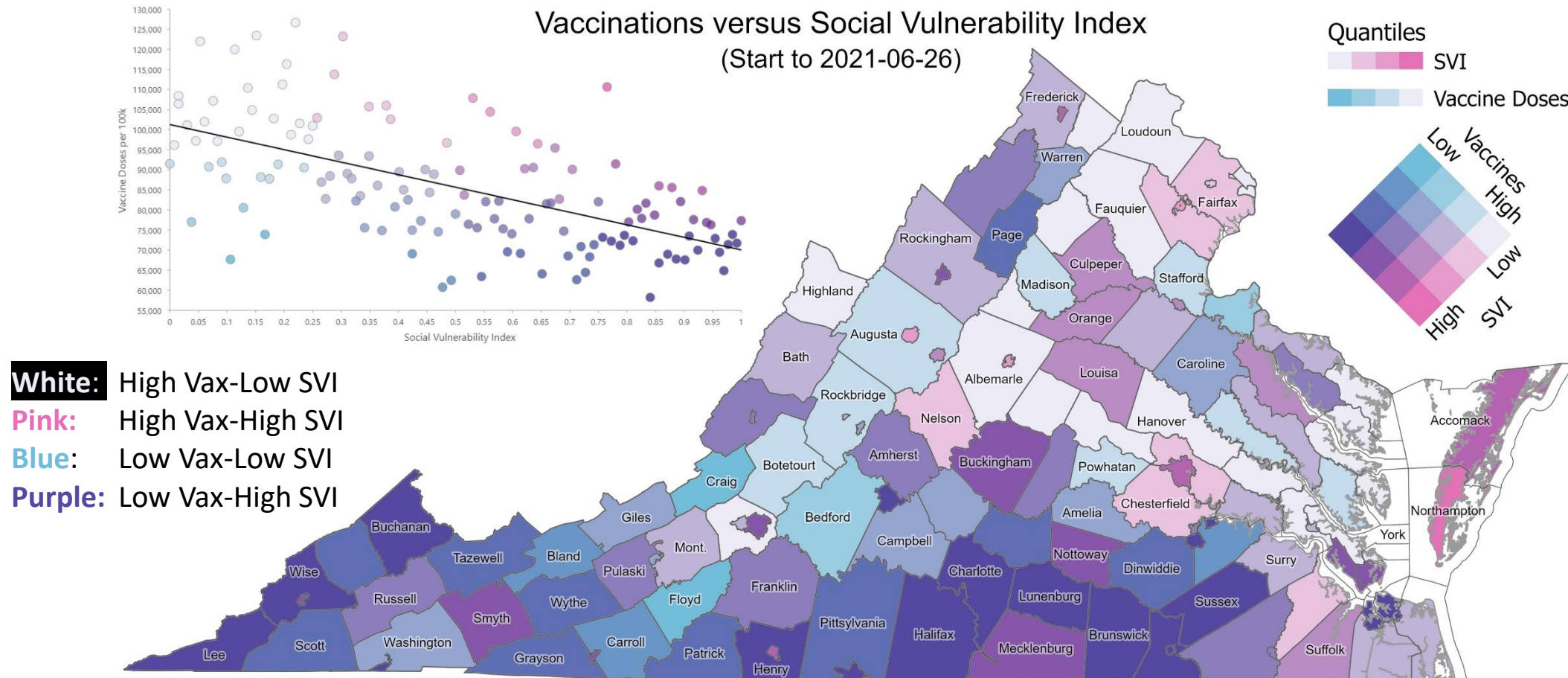


Moran's I = 0.031106, Z-Score = 0.547901, P-Value = 0.58376  
No Residual Autocorrelation Detected

# Social Vulnerability and Total Vaccination Rates

## Comparison of social vulnerability and total vaccination rate since the start of vaccination

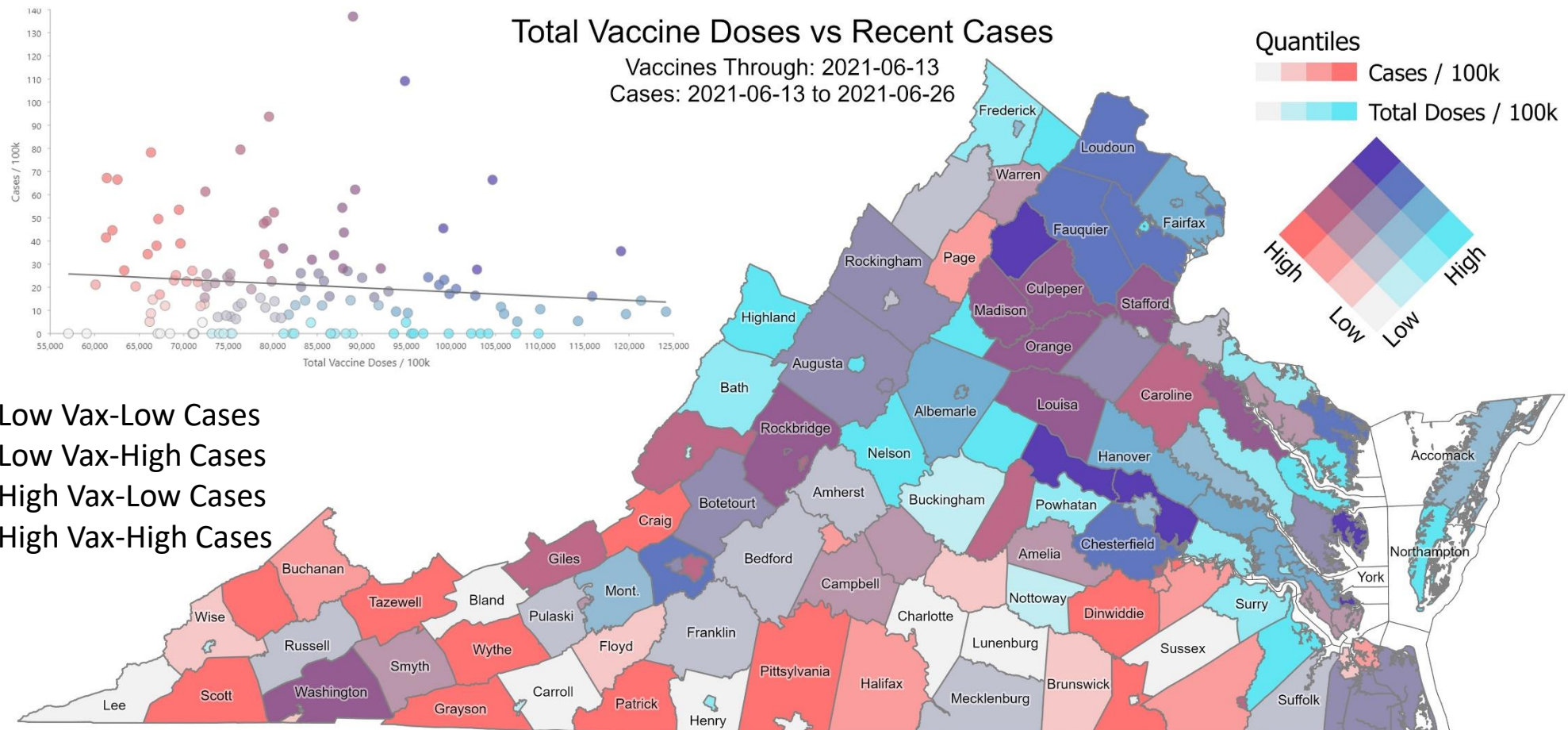
- **Social Vulnerability:** Each county's Social Vulnerability Index (CDC) compared with the level of vaccination





# Vaccination and and Recent Case Rates

Comparison of total vaccination rate and case prevalence in the last month



# Model Update – Adaptive Fitting

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# Adaptive Fitting Approach

## Each county fit precisely, with recent trends used for future projection

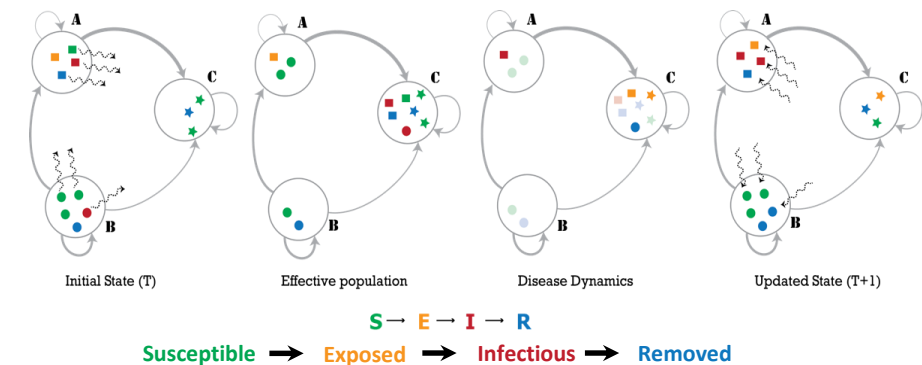
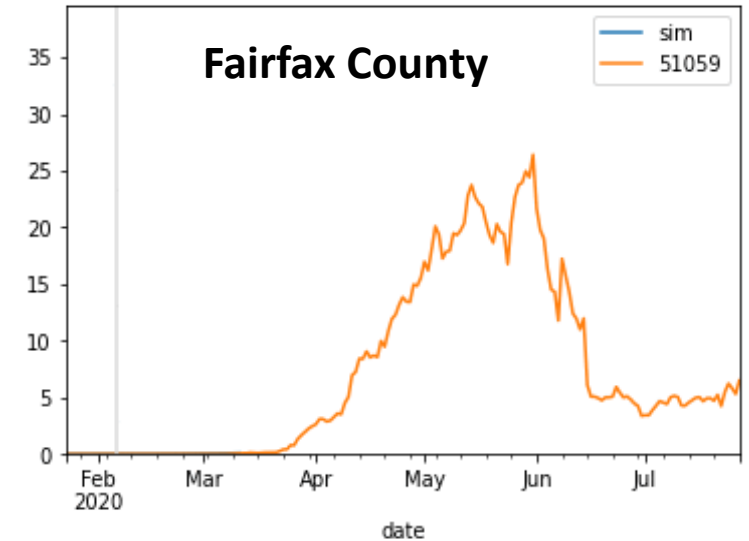
- Allows history to be precisely captured, and used to guide bounds on projections

## Model: An alternative use of the same meta-population model, PatchSim

- Allows for future “what-if” Scenarios to be layered on top of calibrated model
- Eliminates connectivity between patches, to allow calibration to capture the increasingly unsynchronized epidemic

## External Seeding: Steady low-level importation

- Widespread pandemic eliminates sensitivity to initial conditions
- Uses steady 1 case per 10M population per day external seeding



# Using Ensemble Model to Guide Projections

Ensemble methodology that combines the Adaptive with machine learning and statistical models such as:

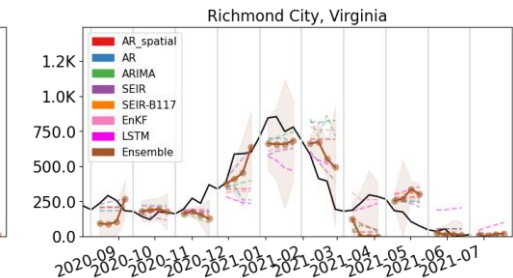
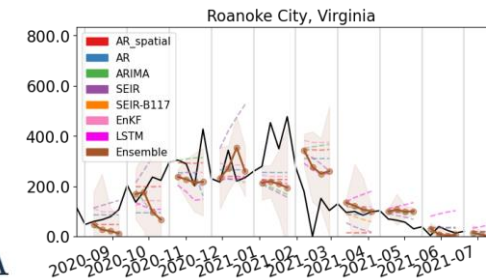
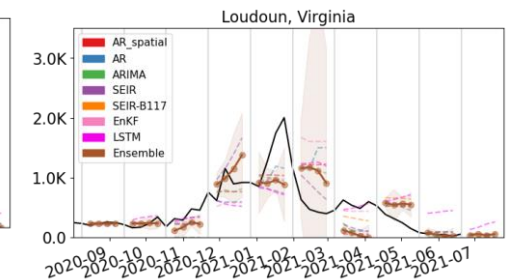
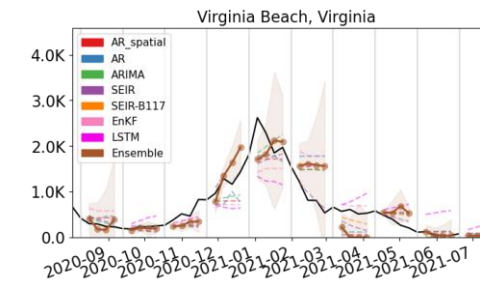
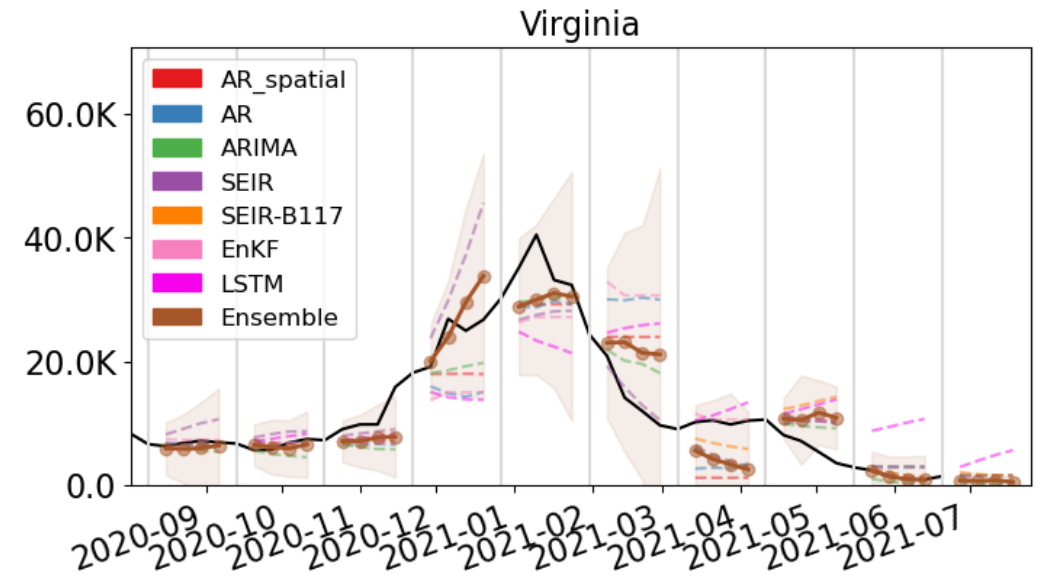
- Autoregressive (AR, ARIMA)
- Neural networks (LSTM)
- Kalman filtering (EnKF)

Weekly forecasts done at county level.

Models chosen because of their track record in disease forecasting and to increase diversity and robustness.

Ensemble forecast provides additional 'surveillance' for making scenario-based projections.

Also submitted to CDC Forecast Hub.



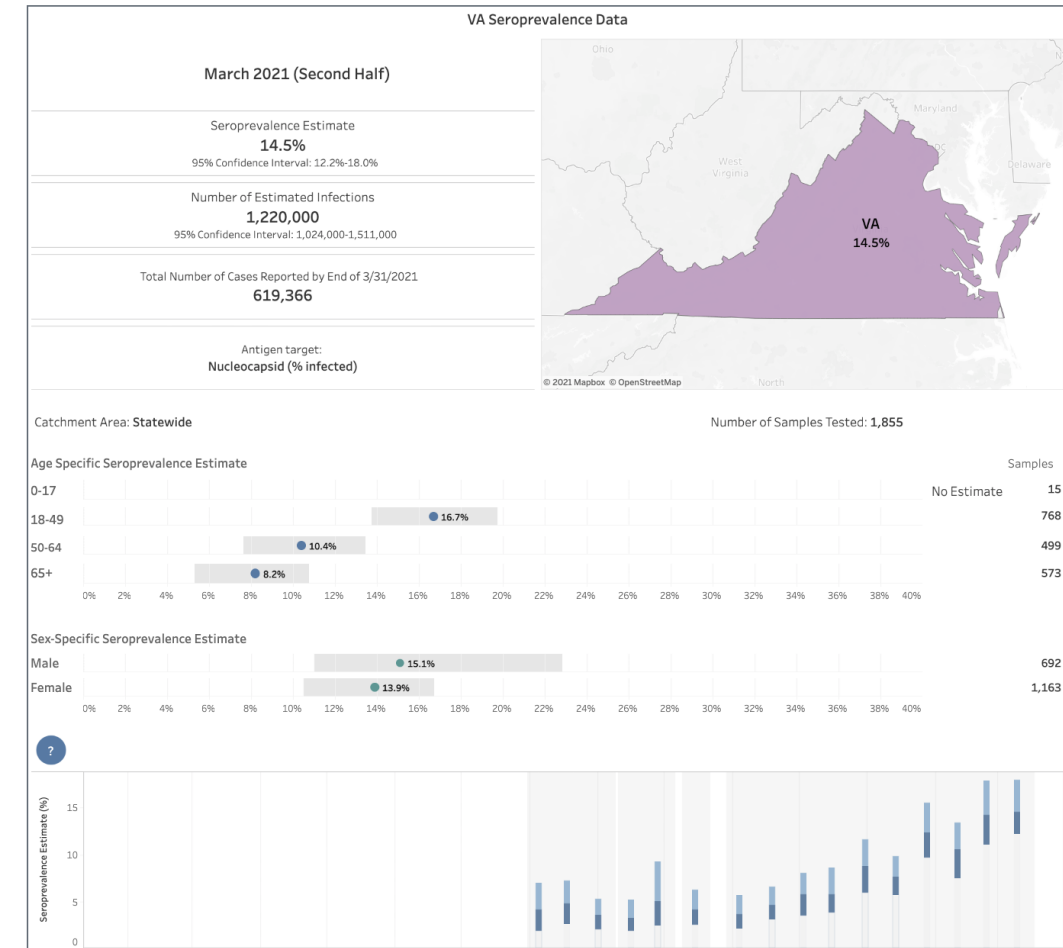
# Seroprevalence updates to model design

**Several seroprevalence studies provide better picture of how many actual infections have occurred**

- CDC Nationwide Commercial Laboratory Seroprevalence Survey estimated 14.5% [12% – 18%] seroprevalence as of March 4<sup>th</sup> – 17<sup>th</sup> up from 10.5% a month earlier

**These findings are equivalent to an ascertainment ratio of ~2x in the future, with bounds of (1.3x to 3x)**

- Thus for 2x there are 2 total infections in the population for every confirmed case recently
- This measure now fully tracks the estimated ascertainment over time
- Uncertainty design has been shifted to these bounds (previously higher ascertainments as was consistent earlier in the pandemic were being used)



<https://covid.cdc.gov/covid-data-tracker/#national-lab>

# Calibration Approach

- **Data:**
  - County level case counts by date of onset (from VDH)
  - Confirmed cases for model fitting
- **Calibration:** fit model to observed data and ensemble's forecast
  - Tune transmissibility across ranges of:
    - Duration of incubation (5-9 days), infectiousness (3-7 days)
    - Undocumented case rate (1x to 7x) guided by seroprevalence studies
    - Detection delay: exposure to confirmation (4-12 days)
  - Approach captures uncertainty, but allows model to precisely track the full trajectory of the outbreak
- **Project:** future cases and outcomes generated using the collection of fit models run into the future
  - **Mean trend from last 7 days of observed cases and first week of ensemble's forecast used**
  - Outliers removed based on variances in the previous 3 weeks
  - 2 week interpolation to smooth transitions in rapidly changing trajectories

## COVID-19 in Virginia:

Dashboard Updated: 6/30/2021  
Data entered by 5:00 PM the prior day.

Cases, Hospitalizations and Deaths					
Total Cases*		Total Hospitalizations**		Total Deaths	
680,340		30,458		11,415	
(New Cases: 275) <sup>^</sup>					
Confirmed†	Probable†	Confirmed†	Probable†	Confirmed†	Probable†
529,535	150,805	28,901	1,557	9,635	1,780

\* Includes both people with a positive test (Confirmed), and symptomatic with a known exposure to COVID-19 (Probable).

\*\* Hospitalization of a case is captured at the time VDH performs case investigation. This underrepresents the total number of hospitalizations in Virginia.

<sup>^</sup>New cases represent the number of confirmed and probable cases reported to VDH in the past 24 hours.

† VDH adopted the updated CDC COVID-19 confirmed and probable surveillance case definitions on August 27, 2020. Found here: <https://www.cdc.gov/nndss/conditions/coronavirus-disease-2019-covid-19/case-definition/2020/08/05/>

Outbreaks	
Total Outbreaks*	Outbreak Associated Cases
<b>3,692</b>	<b>77,452</b>

\* At least two (2) lab confirmed cases are required to classify an outbreak.

Testing (PCR Only)	
Testing Encounters PCR Only*	Current 7-Day Positivity Rate PCR Only**
<b>7,695,293</b>	<b>1.6%</b>

\* PCR refers to "Reverse transcriptase polymerase chain reaction laboratory testing."

\*\* Lab reports may not have been received yet. Percent positivity is not calculated for days with incomplete data.

Multisystem Inflammatory Syndrome in Children	
Total Cases*	Total Deaths
<b>75</b>	<b>0</b>

\*Cases defined by CDC HAN case definition: <https://emergency.cdc.gov/han/2020/han00432.asp>

Accessed 10:00am June 30, 2021

<https://www.vdh.virginia.gov/coronavirus/>

# Scenarios – Transmission Conditions

- Variety of factors continue to drive transmission rates
  - Seasonal impact of weather patterns, travel and gatherings, fatigue and premature relaxation of infection control practices
- Plausible levels of transmission can be bounded by past experience
  - Assess transmission levels at the county level from May 1, 2020 – Sept 1, 2020 or current, whichever is highest
- Projection Scenario:
  - **Adaptive:** Control remains as is currently experienced into the future
- Additional study scenarios with Fall Resurgence:
  - **Fall:** Resurgence to worst of Fall 2020 starting in September and ramping up quickly
  - **Fatigued Control:**
    - Highest level of transmission (95<sup>th</sup> percentile) increased by additional 5%
    - Transition to this level over 4 weeks, remain at this level for the summer, then return to Adaptive

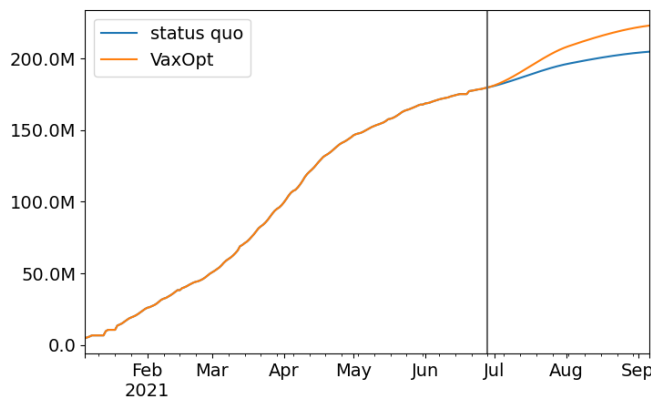
# Scenarios – Vaccination Conditions

## Vaccine Characteristics

- **Pfizer/Moderna:** 50% after first dose, 95% after second dose (3.5 week gap)
- **J & J :** 67% efficacy after first (and only) dose
- Delay to efficacy from doses is 14 days, immunity lasts at least 7m ([NEJM study](#))

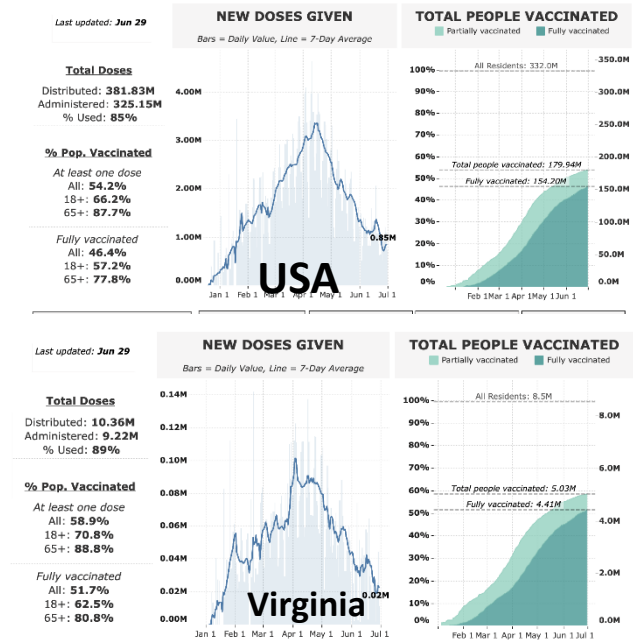
## Vaccine Administration Scenarios

- **Status quo (no label):** COVIDcast corrected acceptance estimates (statewide mean is ~73%) reached by Labor Day.
- **Optimistic (VaxOpt):** Expand VA mean acceptance to ~85% (with all counties reaching a minimum of 65%, max of 95%).
- Acceptance at county level = regional acceptance +/- relative current vax
- Front-loaded rollout (two-thirds of the remaining in half the time)



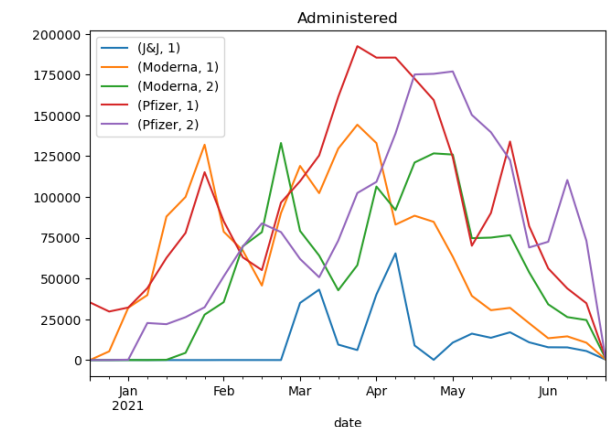
	status quo	VaxOpt
<b>Monthly first doses</b>		
Date		
2020-12-31	113.3K	113.3K
2021-01-31	655.9K	655.9K
2021-02-28	569.7K	569.7K
2021-03-31	1.3M	1.3M
2021-04-30	1.2M	1.2M
2021-05-31	583.5K	583.5K
2021-06-30	241.3K	254.8K
2021-07-31	350.1K	784.5K
2021-08-31	175.7K	390.1K
2021-09-30	19.1K	42.2K

	status quo	VaxOpt
<b>Cumulative</b>		
Date		
2020-12-31	113.3K	113.3K
2021-01-31	769.2K	769.2K
2021-02-28	1.3M	1.3M
2021-03-31	2.7M	2.7M
2021-04-30	3.8M	3.8M
2021-05-31	4.4M	4.4M
2021-06-30	4.6M	4.7M
2021-07-31	5.0M	5.4M
2021-08-31	5.2M	5.8M
2021-09-30	5.2M	5.9M



Source: [https://ckelly17.github.io/vaccine\\_dashboard.html](https://ckelly17.github.io/vaccine_dashboard.html)

## Weekly VA doses administered by manufacturer





# Scenarios – Delta $\delta$ Variant Condition

Variant Delta  $\delta$  has exhibited ability to outcompete other variants and its growth has become more predictable

- Variant Alpha  $\alpha$  (B.1.1.7) reached dominance in Virginia and US but is now declining

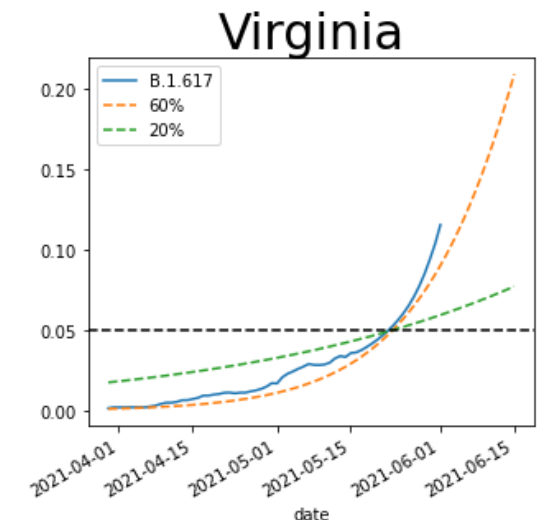
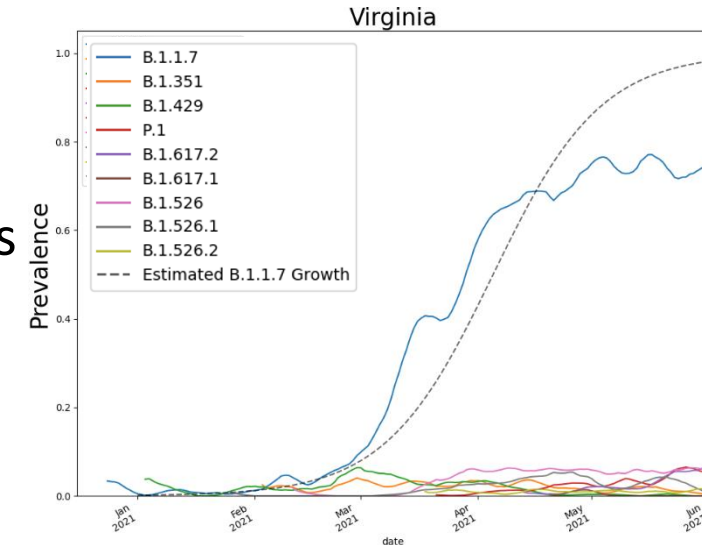
**Transmissibility:** Delta's relative transmissibility compared to Alpha is better understood (60% more transmissible) and its growth can be estimated

**Immune Escape:** Delta has been observed to evade immunity, both natural and vaccine-induced, however, uncertainty remains high thus this is **NOT** factored into the model

**Severity:** Delta, similar to alpha, appears to cause more severe illness with estimates ranging from 50% to 200%, at the moment assume 60%

## Delta Variant Scenario:

- Continues to grow on 60% more transmissible trajectory, reaches 50% prevalence on July 2<sup>nd</sup> and is also 60% more severe than alpha



# Projection Scenarios – Combined Conditions

Name	Txm Controls	Variant Boosting	Vax	Description
Adaptive	C	None	SQ	Likely trajectory based on conditions remaining similar to how they are now
Adaptive-VaxOpt	C	None	VO	Vaccination through Labor Day reaches an optimistically high level of expanded coverage (85%)
Adaptive-Delta	C	60%	SQ	Likely trajectory based on conditions remaining similar to now, but with increasing prevalence of Delta variant
Adaptive-Delta-VaxOpt	C	60%	VO	Vaccination through Labor Day reaches an optimistically high level of expanded coverage (85%), with increasing prevalence of Delta variant

**Transmission Controls:** C = Current levels persist into the future

F = Fatiguing controls drift to worst levels of last summer and persist

**Variant Boosting:** None = Variety of variants, no future txm boosting, but with severity impacts from current levels

60% = Prevalence of Delta ramps up according to logistic growth and is 60% more transmissible

**Vaccinations:** SQ = Status quo acceptance leads to low rates of vaccination through the summer

VO = Vaccination acceptance optimistically expands with increased rates through the summer



# Study Scenarios – Additional Conditions

Name	Abbv	Description
Fall Surge	Fall	Shift to worst transmission from Fall 2020 starting on Labor day and continue for 4 weeks to replicate increased transmission from seasonal effects and changes in human activities
Fatiguing Control Measures	FatigueControl	Worst case trajectory if control conditions deteriorate to highest transmission rates of the past

## Added to existing conditions:

**Variant Boosting:** None = Variety of variants, no future txm boosting, but with severity impacts from current levels  
60% = Prevalence of Delta ramps up according to logistic growth and is 60% more transmissible

**Vaccinations:** SQ = Status quo acceptance leads to low rates of vaccination through the summer  
VO = Vaccination acceptance optimistically expands with increased rates through the summer

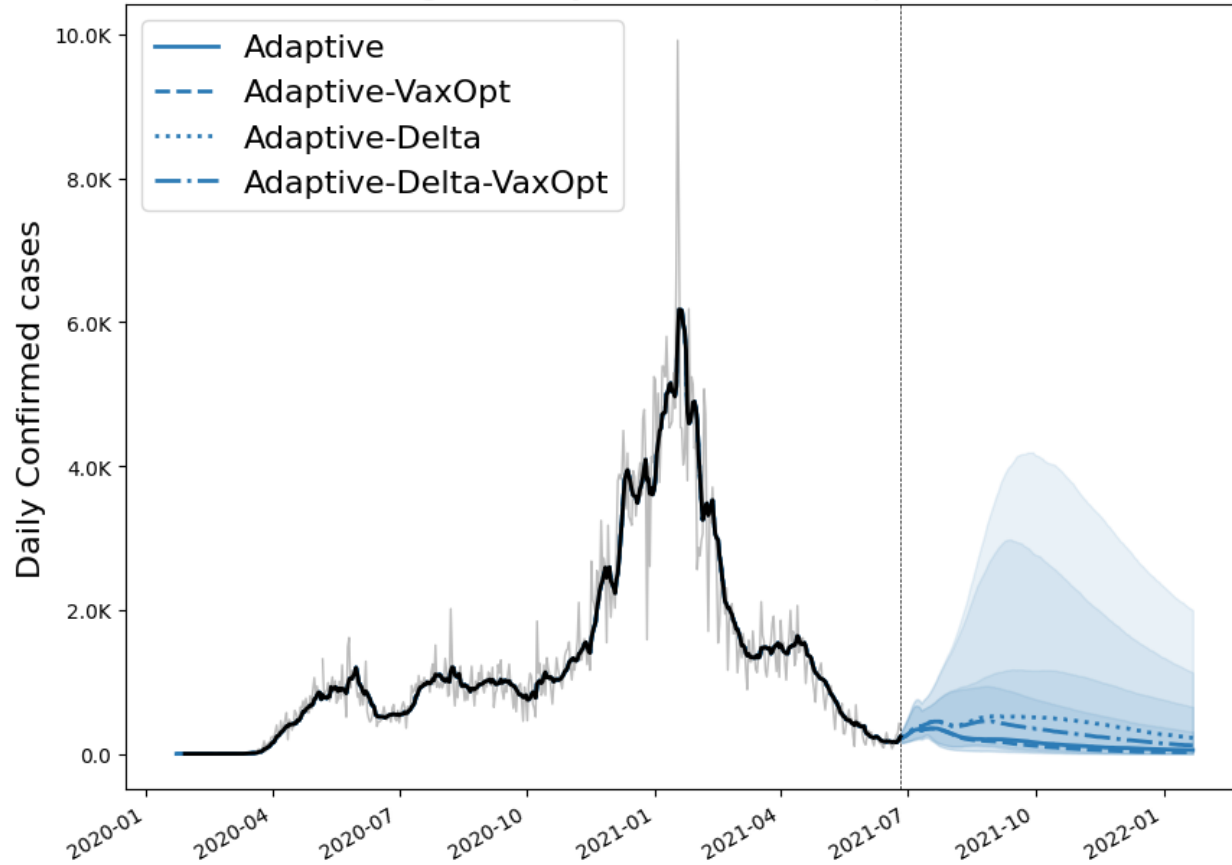
# Model Results

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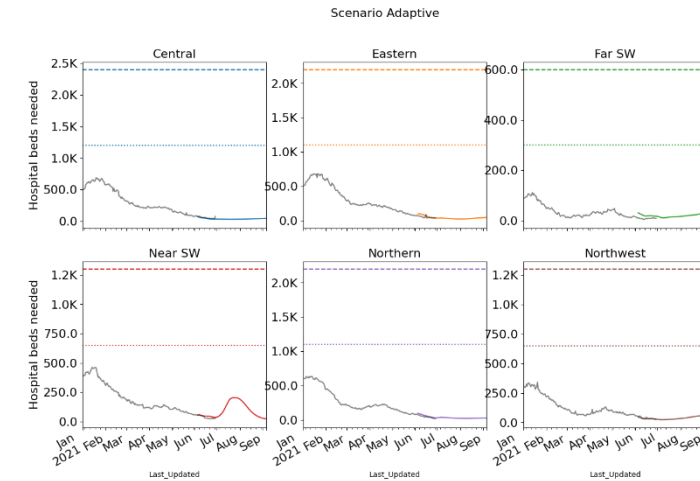
# Outcome Projections

## Confirmed cases

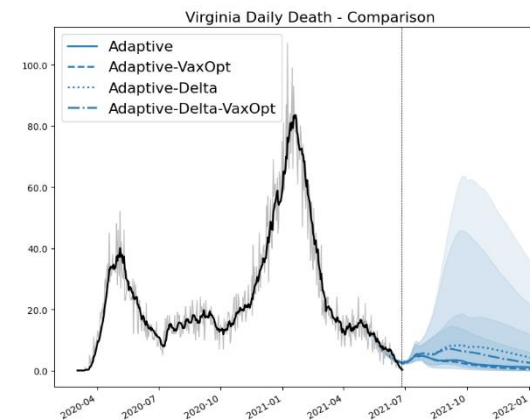
Virginia Daily Confirmed - Comparison



## Estimated Hospital Occupancy

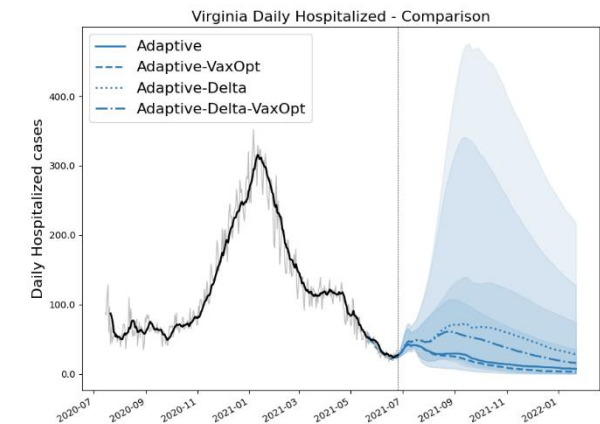


## Daily Deaths



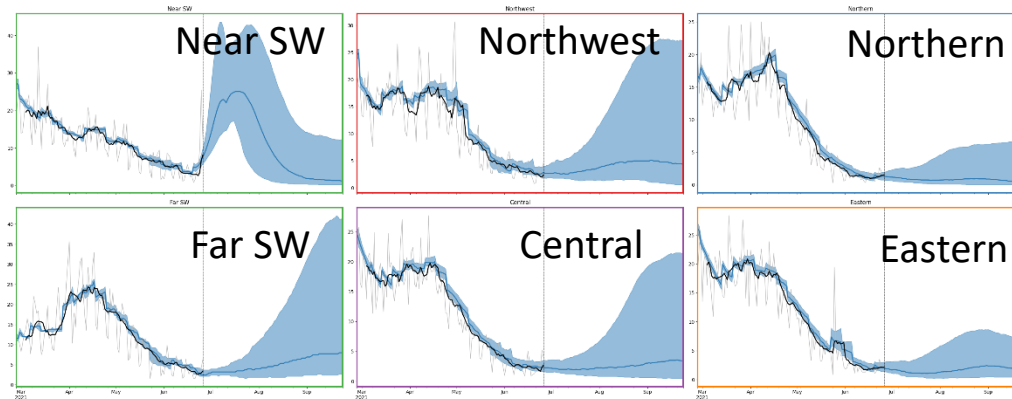
Death ground truth from VDH "Event Date" data, most recent dates are not complete

## Daily Hospitalized

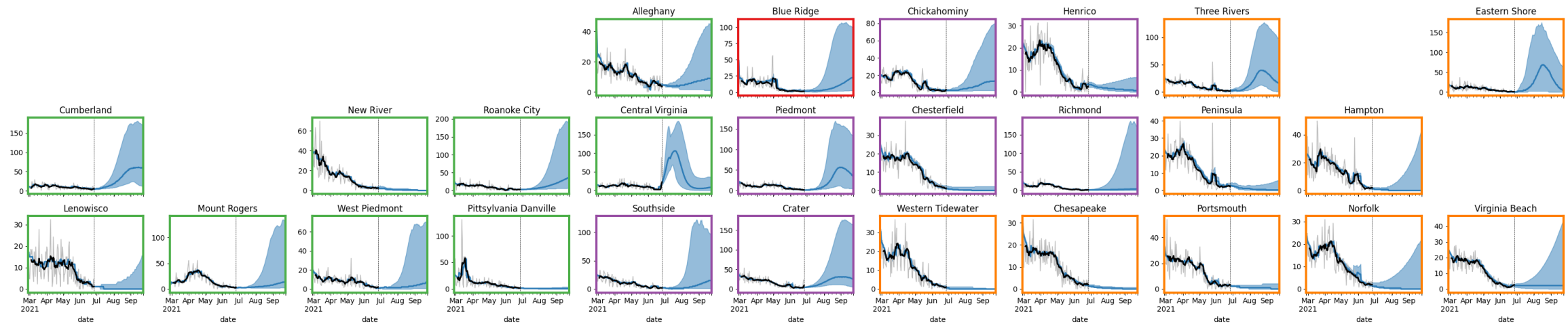


# District Level Projections: Adaptive

## Projections by Region



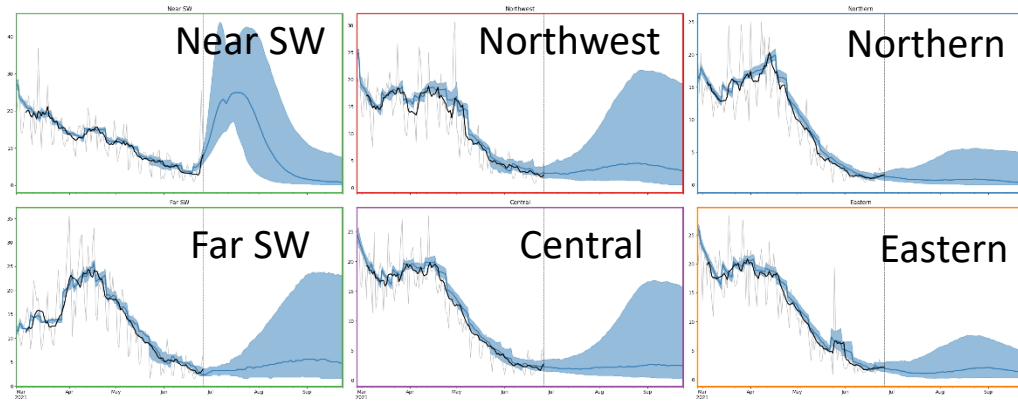
## Projections by District



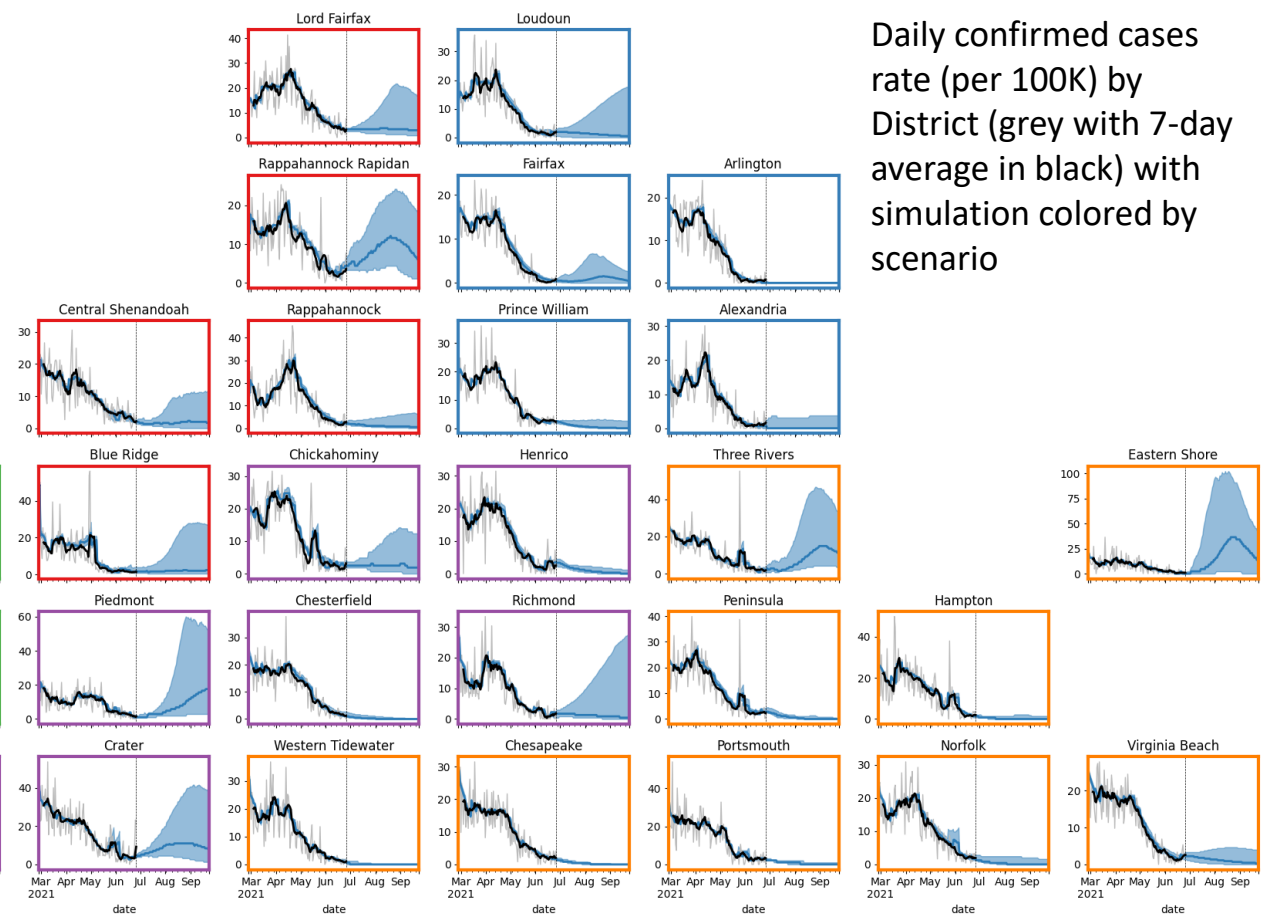
Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario

# District Level Projections: Adaptive-VaxOpt

## Projections by Region



## Projections by District

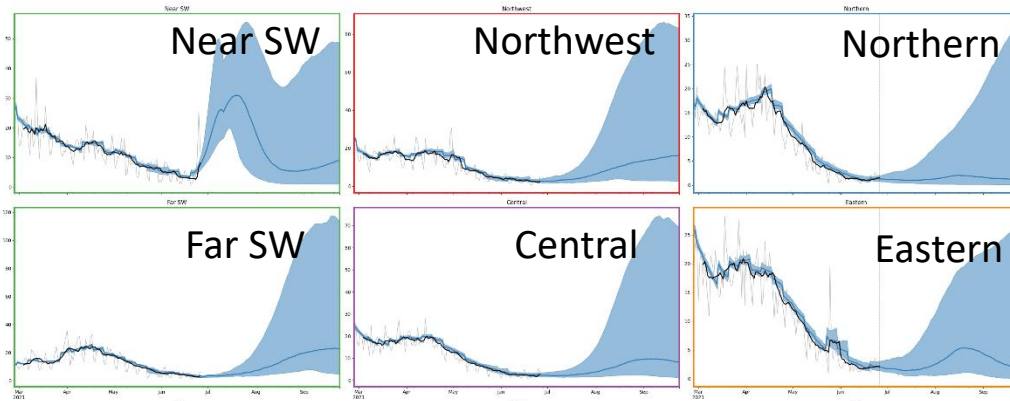


Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario

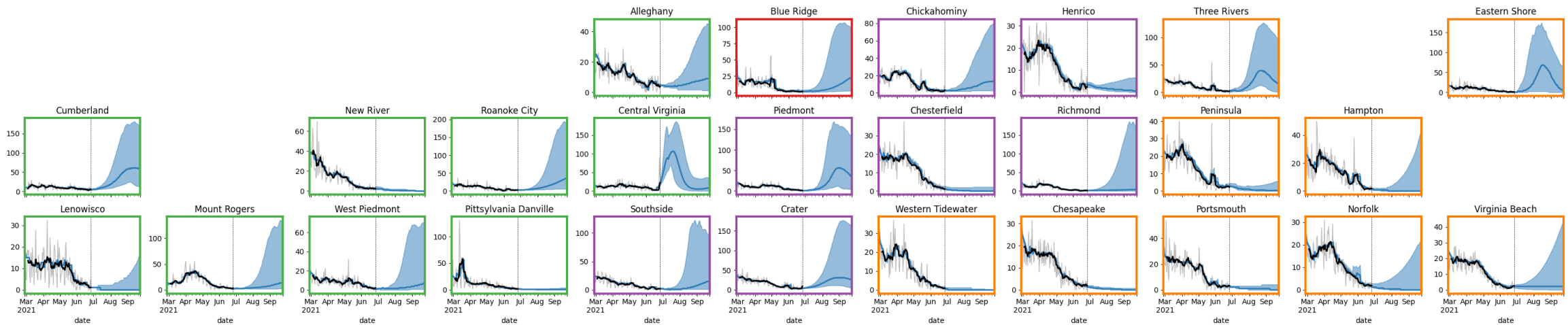


# District Level Projections: Adaptive-Delta

## Projections by Region



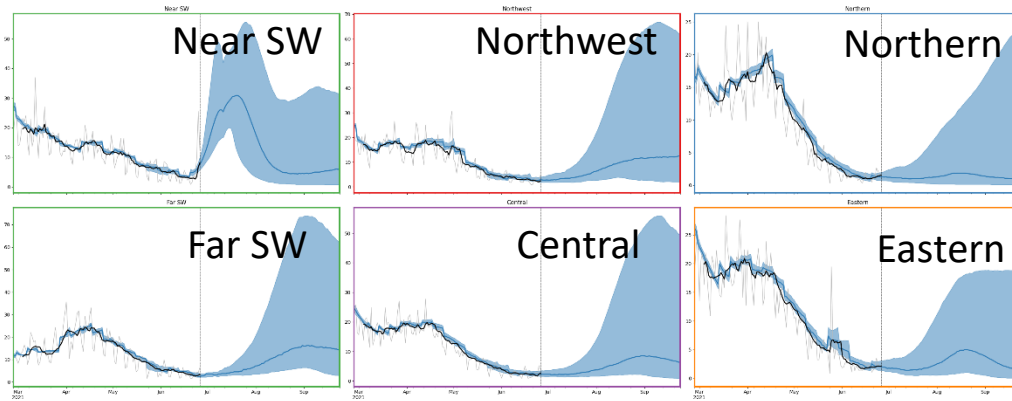
## Projections by District



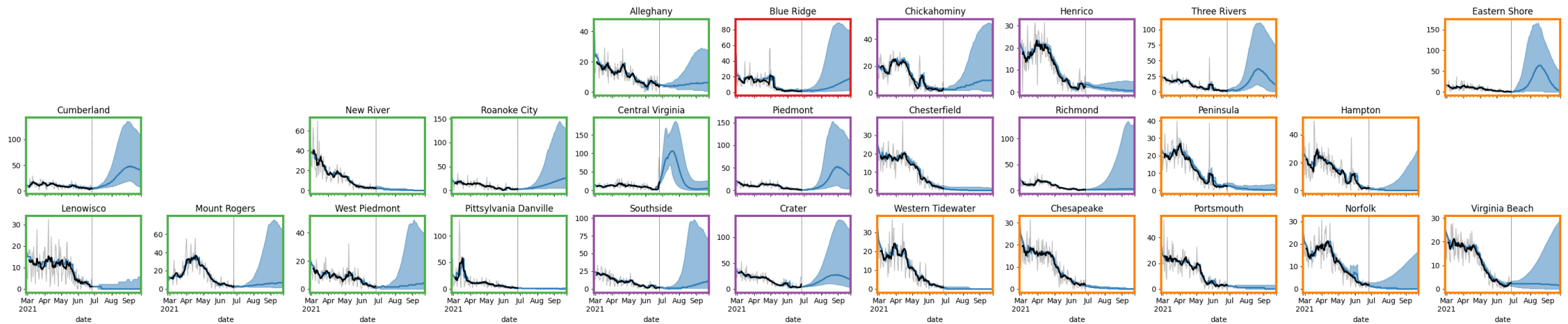
Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario

# District Level Projections: Adaptive-Delta-VaxOpt

## Projections by Region



## Projections by District

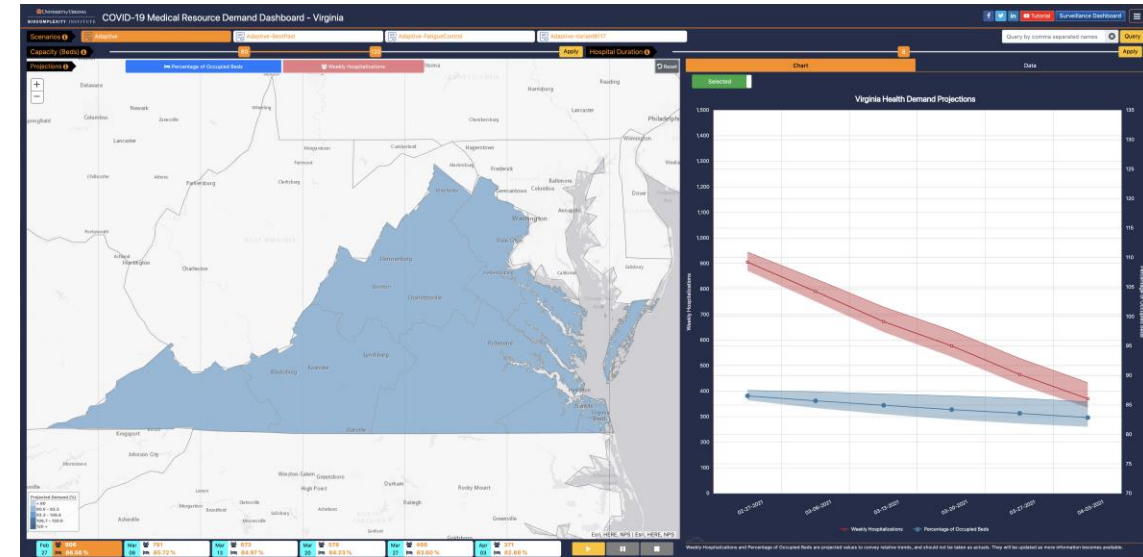
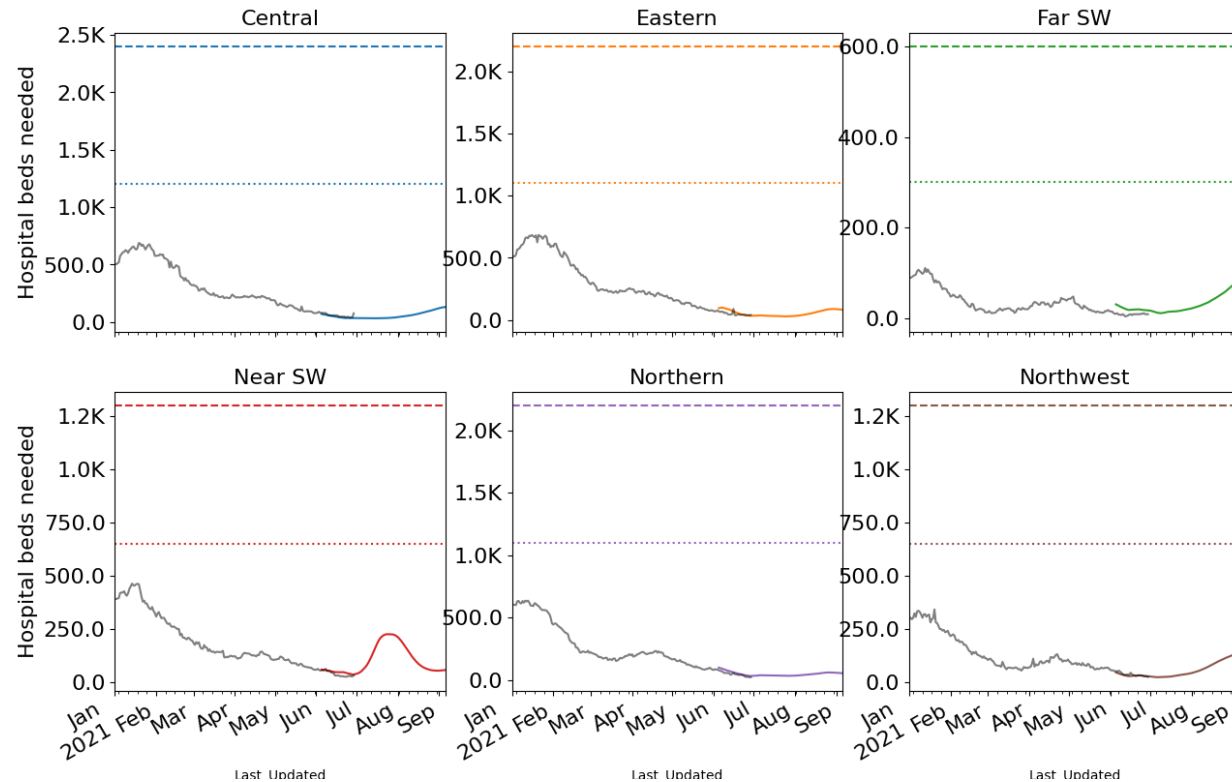


Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario

# Hospital Demand and Bed Capacity by Region

## Capacities\* by Region – Adaptive-Delta

COVID-19 capacity ranges from 80% (dots) to 120% (dash) of total beds



<https://nssac.bii.virginia.edu/covid-19/vmrddash/>

**Adaptive-FatigueControl-Delta scenario shows it remains possible to generate more hospitalizations:**

- Far Southwest and Near Southwest have highest potential

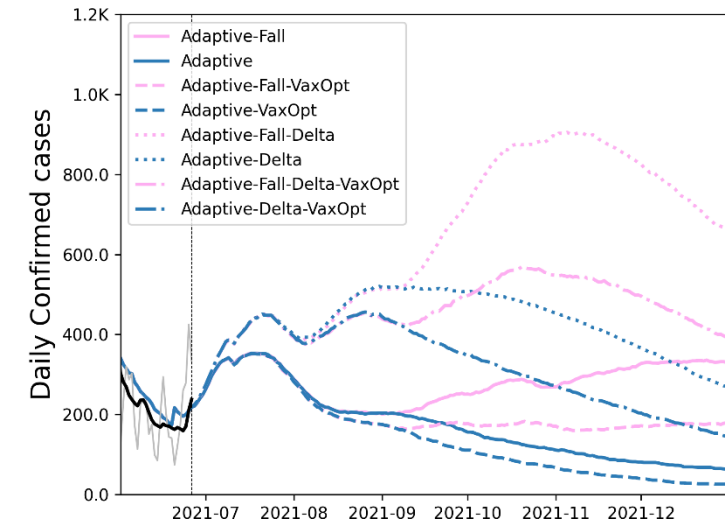
\* Assumes average length of stay of 8 days

# All Scenarios – Fall Surge and Optimistic Vaccination

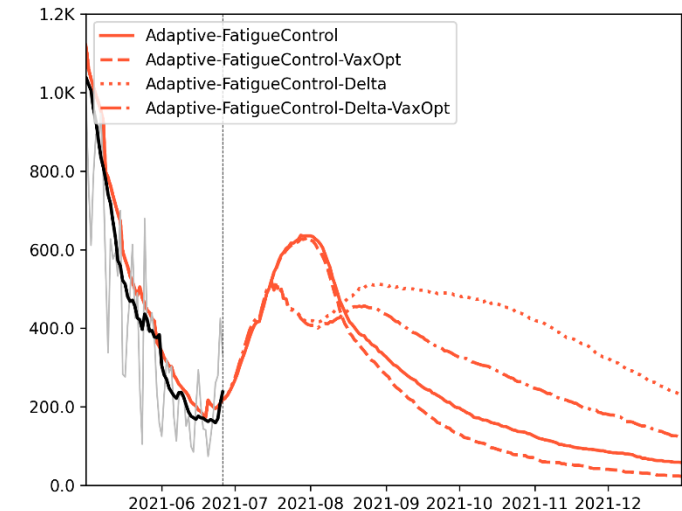
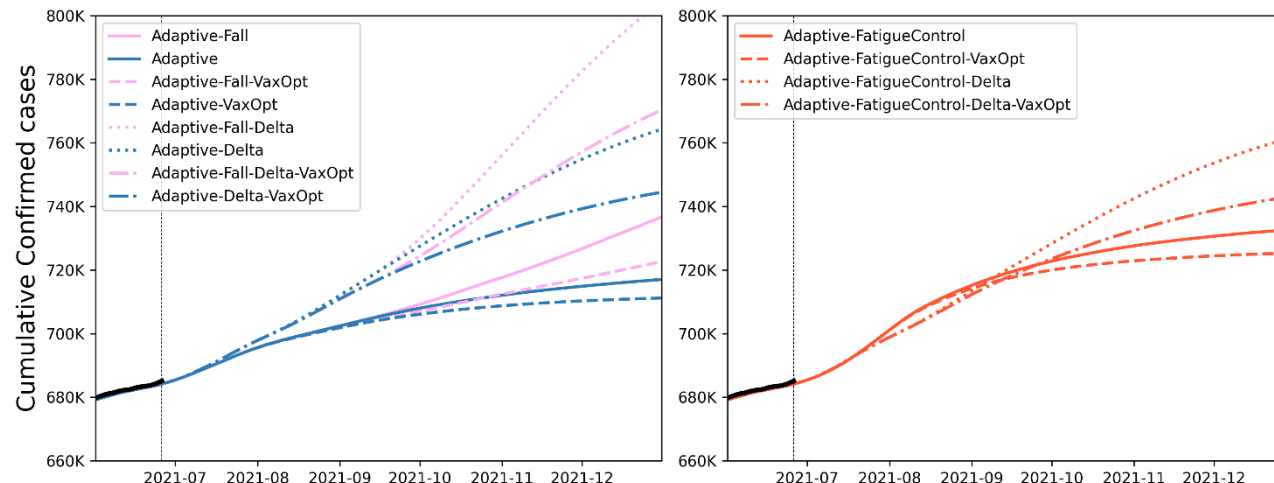
## Impact of expanded vaccine acceptance against a Fall Surge

- Fall Surge on top of more prevalent Delta can create a sizeable spike in cases though it remains below 1000 cases/day
- Expanded vaccination coverage to optimistic levels curtails the impact of a Fall Surge as well as Delta (20K-40K cases)
- Despite range of plausible bad cases for the summer and fall, case rates are relatively moderate compared early 2021

Daily Infections



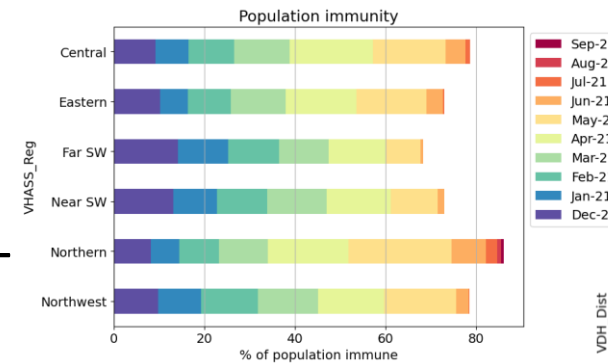
Cumulative Infections



# Virginia's Progress on Population Immunity

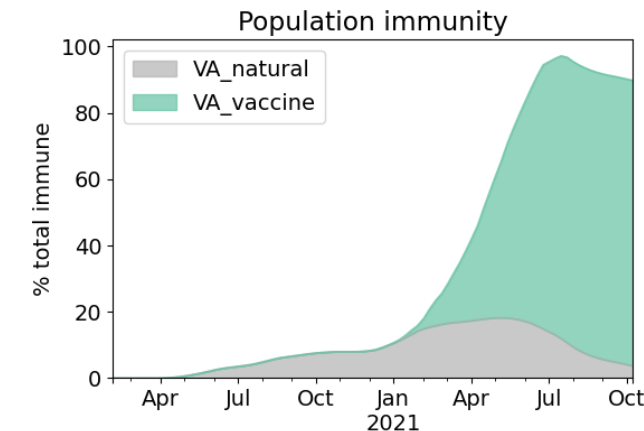
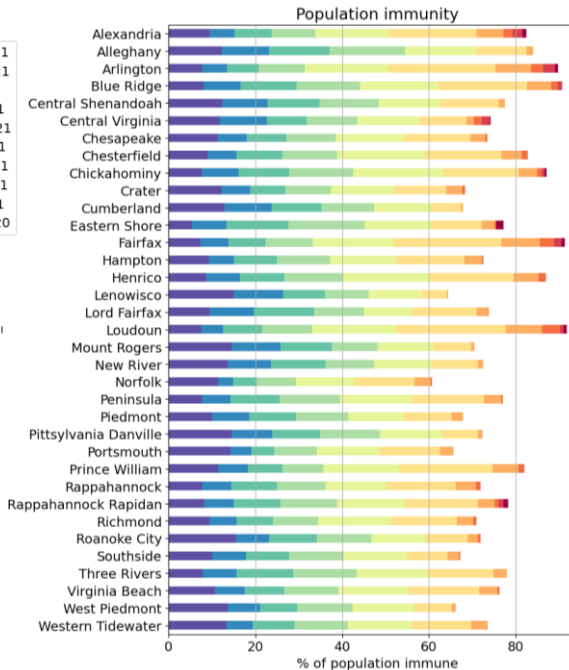
## Natural Immunity and Vaccines combine to produce a population level of immunity

- Duration of immunity from infection with SARS-CoV2 still not well understood
  - We assume a conservative 6 month period of protection for these calculations
  - Natural immunity is well calibrated to recent seroprevalence surveys
- Vaccine induced immunity is likely to last longer, we assume indefinite protection
  - This also assumes that all administered vaccines remain protective against current and future novel variants
- Population immunity depends on a very high proportion of the population getting vaccinated
  - Using regional vaccine acceptance



Region	% immune (est.)*
Central	78%
Eastern	73%
Far SW	66%
Near SW	73%
Northern	82%
Northwest	78%
Virginia	77%

\* As of June 27, 2021





# Additional Analyses

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# Overview of relevant on-going studies

Other projects coordinated with CDC and VDH:

- **Scenario Modeling Hub:** Consortium of academic teams coordinated via MIDAS / CDC to that provides regular national projections based on timely scenarios
- **Genomic Surveillance:** Analyses of genomic sequencing data, VA surveillance data, and collaboration with VA DCLS to identify sample sizes needed to detect and track outbreaks driven by introduction of new variants etc.
- **Mobility Data driven Mobile Vaccine Clinic Site Selection:** Collaboration with VDH state and local, Stanford, and SafeGraph to leverage anonymized cell data to help identify

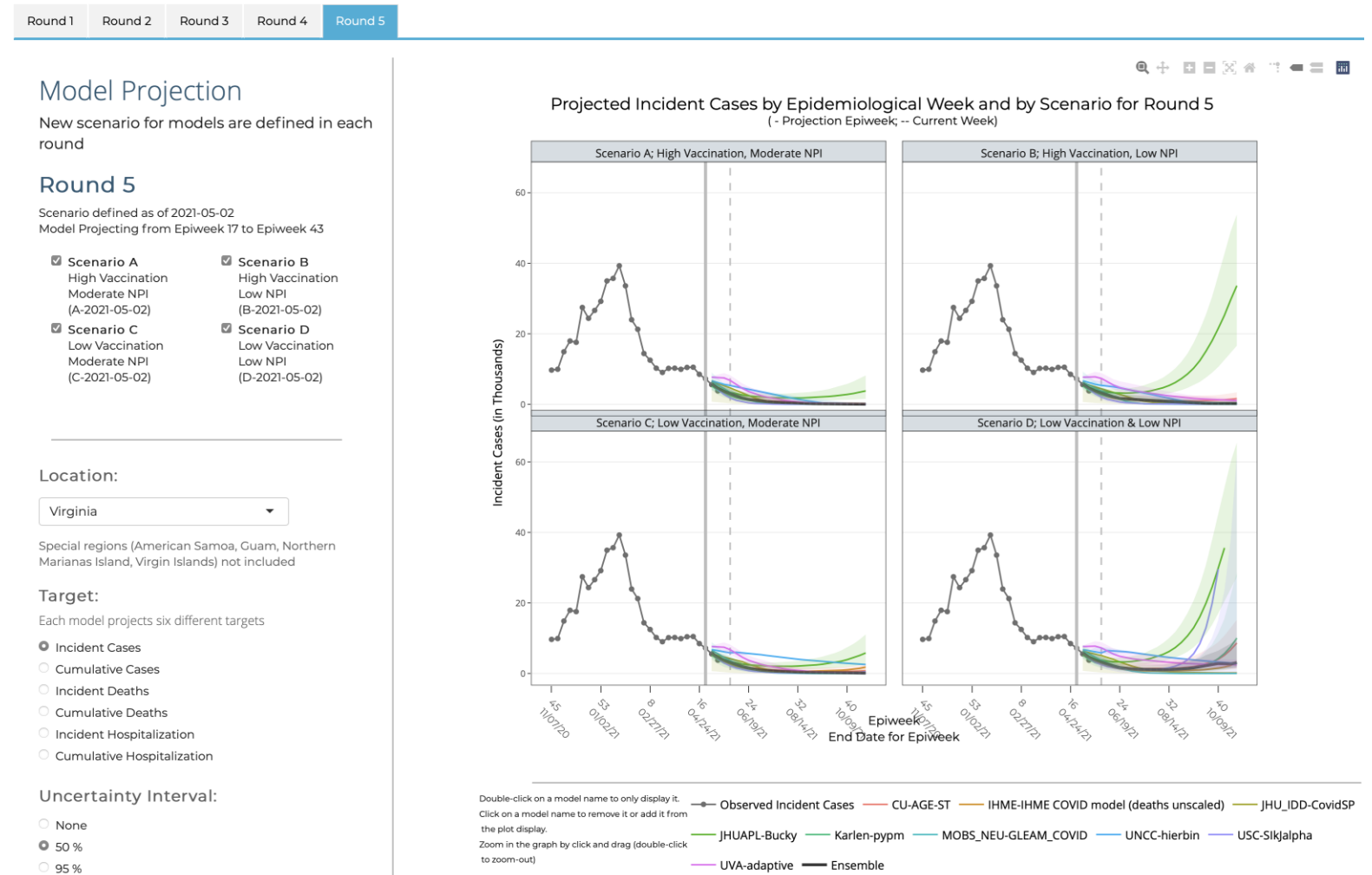
# COVID-19 Scenario Modeling Hub

<https://covid19scenariomodelinghub.org/viz.html>

Collaboration of multiple academic teams to provide national and state-by-state level projections for 4 aligned scenarios that vary vaccine rates (high – low) and levels of control (moderate and low)

- Round 6 concluded and will be available next week
- Round 5 updates now available

*Round 4 Results were published May 5<sup>th</sup>, 2021 in [MMWR](#)*



# COVID-19 Scenario Modeling Hub – Round 6

Round 6 scenarios explore the effects of a variant similar to the Delta (B.1.617.2) against different backgrounds of vaccination.

## Vaccinations by Nov 30

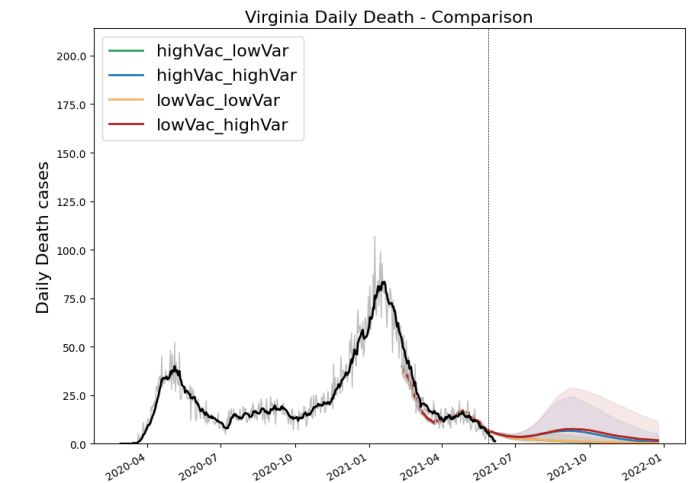
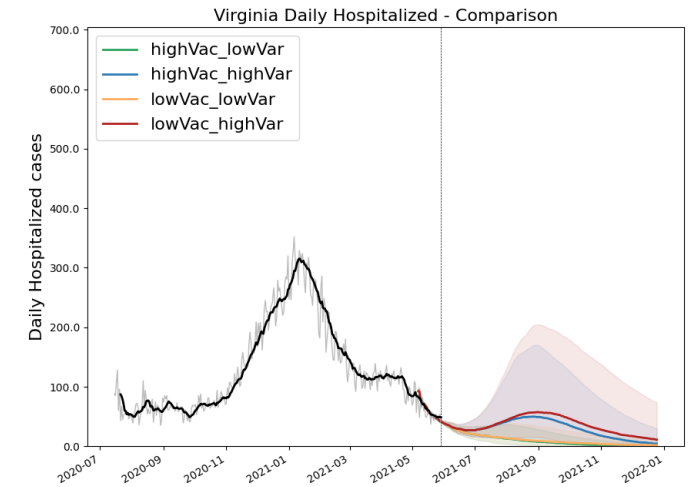
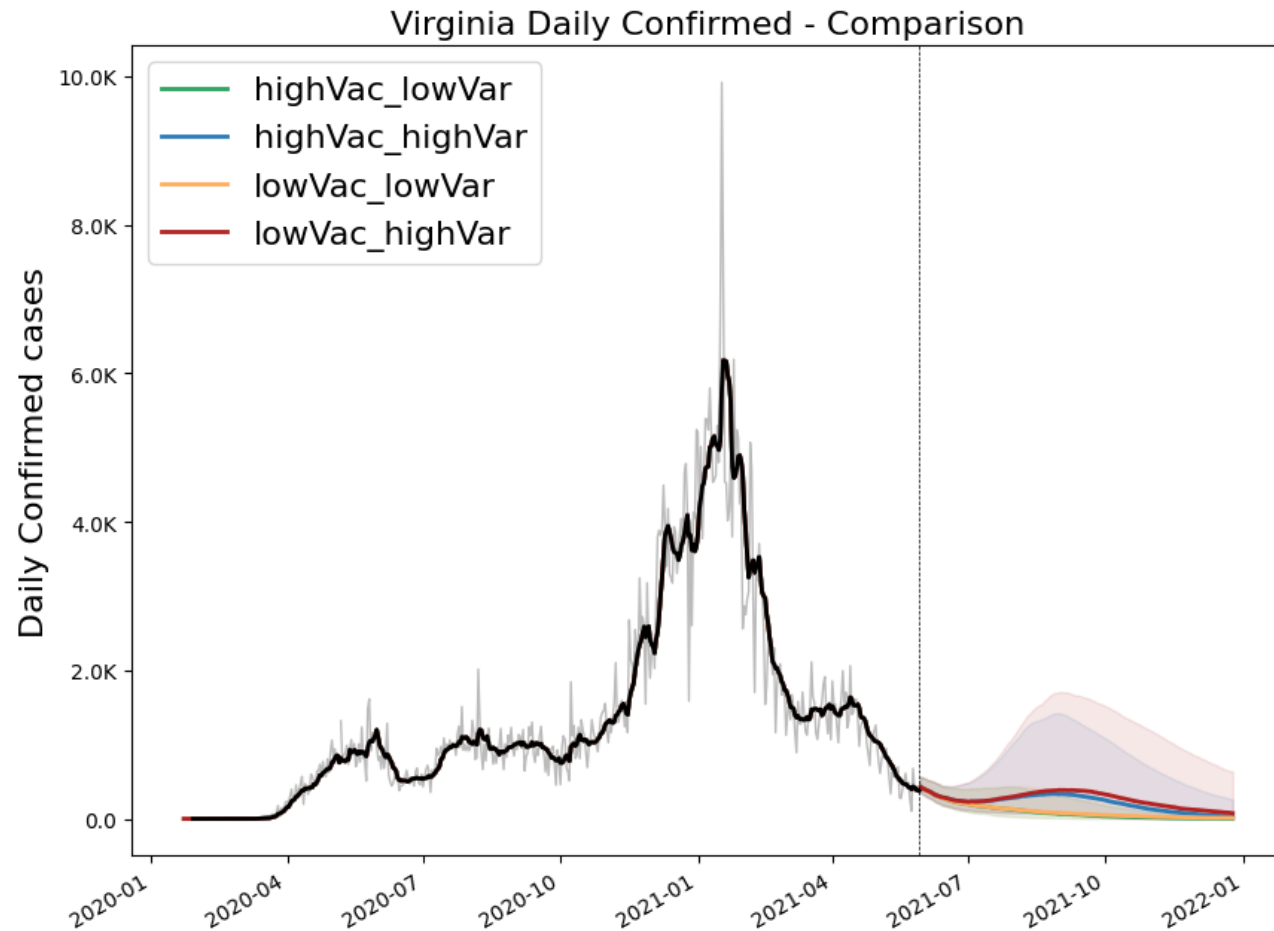
- LowVacc – 68% overall coverage
- HighVacc – 86% overall coverage

## Emerging Variant Impact (5% prevalence on May 29<sup>th</sup>)

- LowVar – 20% more transmissible
- HighVar – 60% more transmissible

	LowVar	HighVar
See more detailed notes for each scenario below	Low Impact Variant (low transmissibility increase, no immune escape)	High Impact Variant (high transmissibility increase, no immune escape)
High Vaccination (Low hesitancy)  HighVacc	<p><b>Scenario A</b></p> <p>Vaccination:</p> <ul style="list-style-type: none"> <li>- Coverage saturates at <b>86% nationally</b> among the vaccine-eligible population* by November 30, 2021**</li> <li>- VE is <b>50%/90%</b> for Pfizer/Moderna against currently circulating variants (1<sup>st</sup> /2<sup>nd</sup> dose)</li> <li>- J&amp;J no longer used</li> </ul> <p>Variant:</p> <ul style="list-style-type: none"> <li>- <b>20% increased transmissibility</b> as compared with B.1.1.7 for B.1.617+ variant. <b>5%</b> prevalence of B.1.617+ nationally on May 29.</li> </ul>	<p><b>Scenario B</b></p> <p>Vaccination:</p> <ul style="list-style-type: none"> <li>- Coverage saturates at <b>86% nationally</b> among the vaccine-eligible population* by November 30, 2021**</li> <li>- VE is <b>50%/90%</b> for Pfizer/Moderna against currently circulating variants (1<sup>st</sup> /2<sup>nd</sup> dose)</li> <li>- J&amp;J no longer used</li> </ul> <p>Variant:</p> <ul style="list-style-type: none"> <li>- <b>60% increased transmissibility</b> as compared with B.1.1.7 for B.1.617+ variant. <b>5%</b> prevalence of B.1.617+ nationally on May 29.</li> </ul>
Low Vaccination (High hesitancy)  LowVacc	<p><b>Scenario C</b></p> <p>Vaccination:</p> <ul style="list-style-type: none"> <li>- Coverage saturates at <b>75% nationally</b> among the vaccine-eligible population* by November 30, 2021**</li> <li>- VE is <b>50%/90%</b> for Pfizer/Moderna against currently circulating variants (1<sup>st</sup> /2<sup>nd</sup> dose) and 60% for JJ (1 dose)</li> <li>- J&amp;J no longer used</li> </ul> <p>Variant:</p> <ul style="list-style-type: none"> <li>- <b>20% increased transmissibility</b> as compared with B.1.1.7 for B.1.617+ variant. <b>5%</b> prevalence of B.1.617+ nationally on May 29.</li> </ul>	<p><b>Scenario D</b></p> <p>Vaccination:</p> <ul style="list-style-type: none"> <li>- Coverage saturates at <b>75% nationally</b> among the vaccine-eligible population* by November 30, 2021**</li> <li>- VE is <b>50%/90%</b> for Pfizer/Moderna against currently circulating variants (1<sup>st</sup> /2<sup>nd</sup> dose) and 60% for JJ (1 dose)</li> <li>- J&amp;J no longer used</li> </ul> <p>Variant:</p> <ul style="list-style-type: none"> <li>- <b>60% increased transmissibility</b> as compared with B.1.1.7 for B.1.617+ variant. <b>5%</b> prevalence of B.1.617+ nationally on May 29.</li> </ul>

# Modeling Hub – Round 6 Prelim Results





# Genomic Sequencing: What size effort is needed?

Focused Questions: What number of sequences do we need to detect a variant of concern/interest in the population?

$$\hat{p} \pm z_{\alpha/2} \sqrt{\frac{\hat{p}(1 - \hat{p})}{n} \cdot \frac{N - n}{N - 1}}$$

## Experiment Details:

- Consider two periods of COVID prevalence high and low (Jan 2021 and June 2020)
- Total infections taken from adaptive
- Confirmed cases from historical data
- Two counties: Fairfax, Montgomery
- 95% Confidence Interval
- +/- 20% of true prevalence

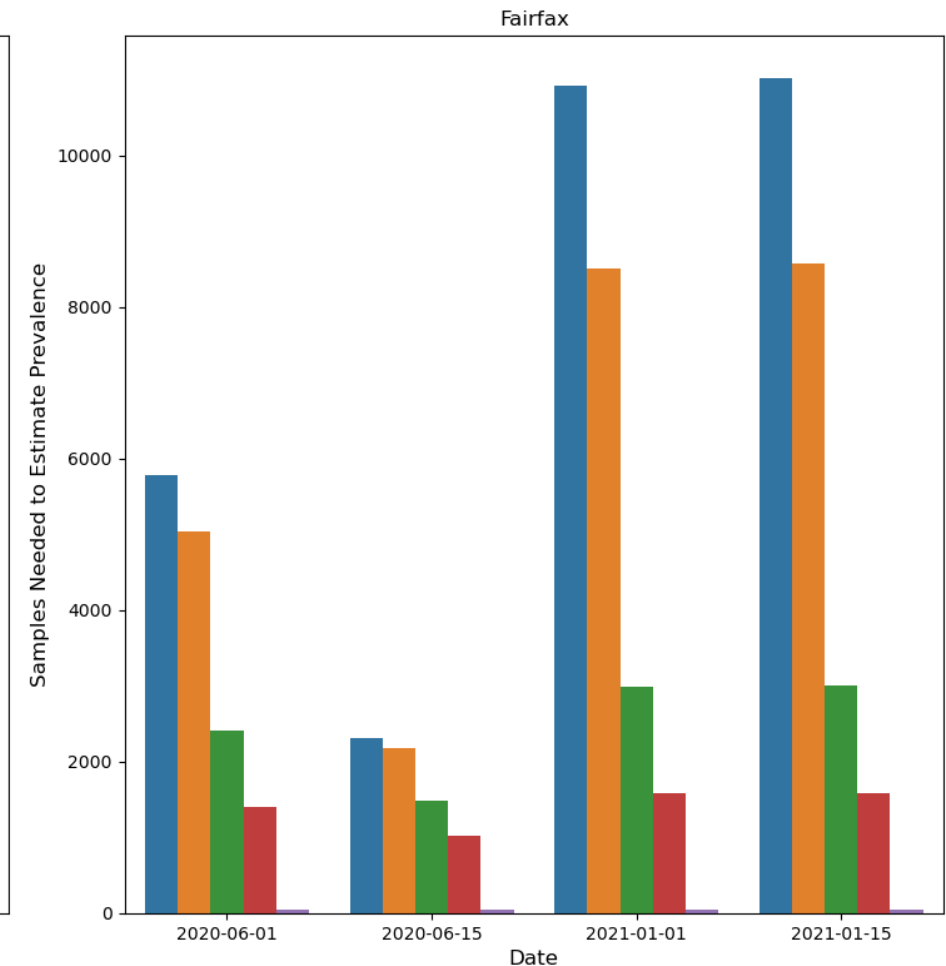
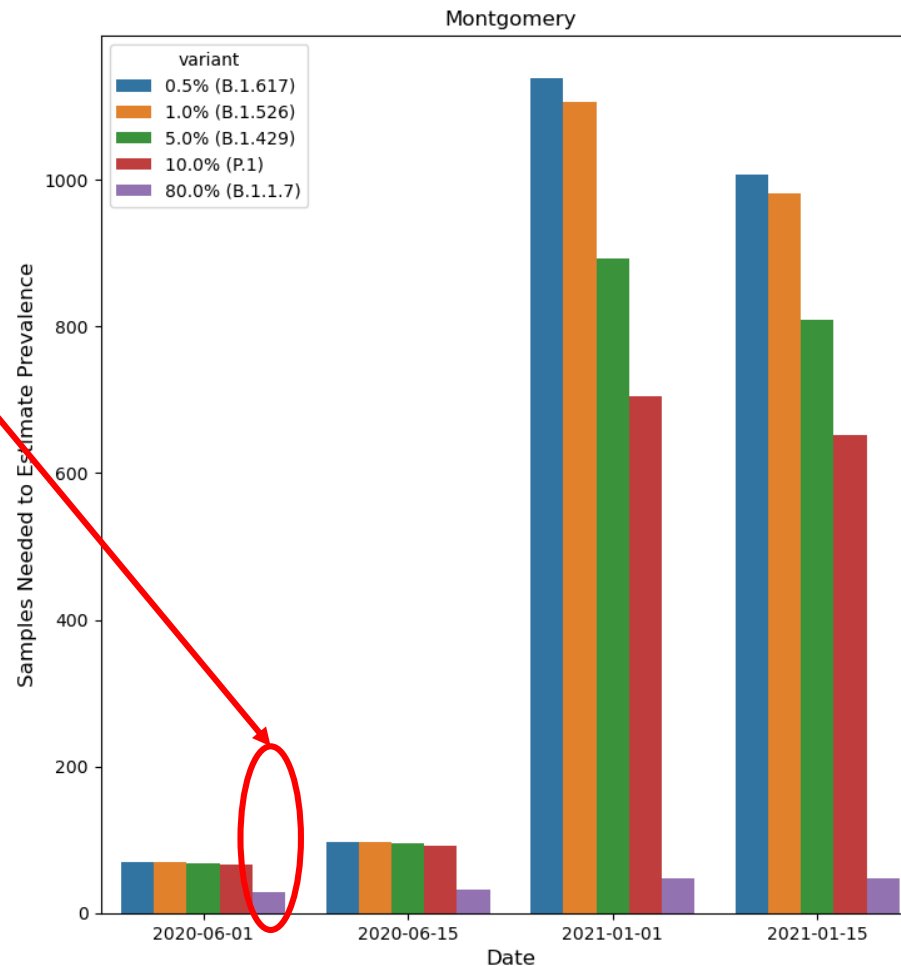
Window size: 14 days

Assumptions:

Test pool is representative  
Sequences are of sufficient quality and timeliness to be representative of the window.

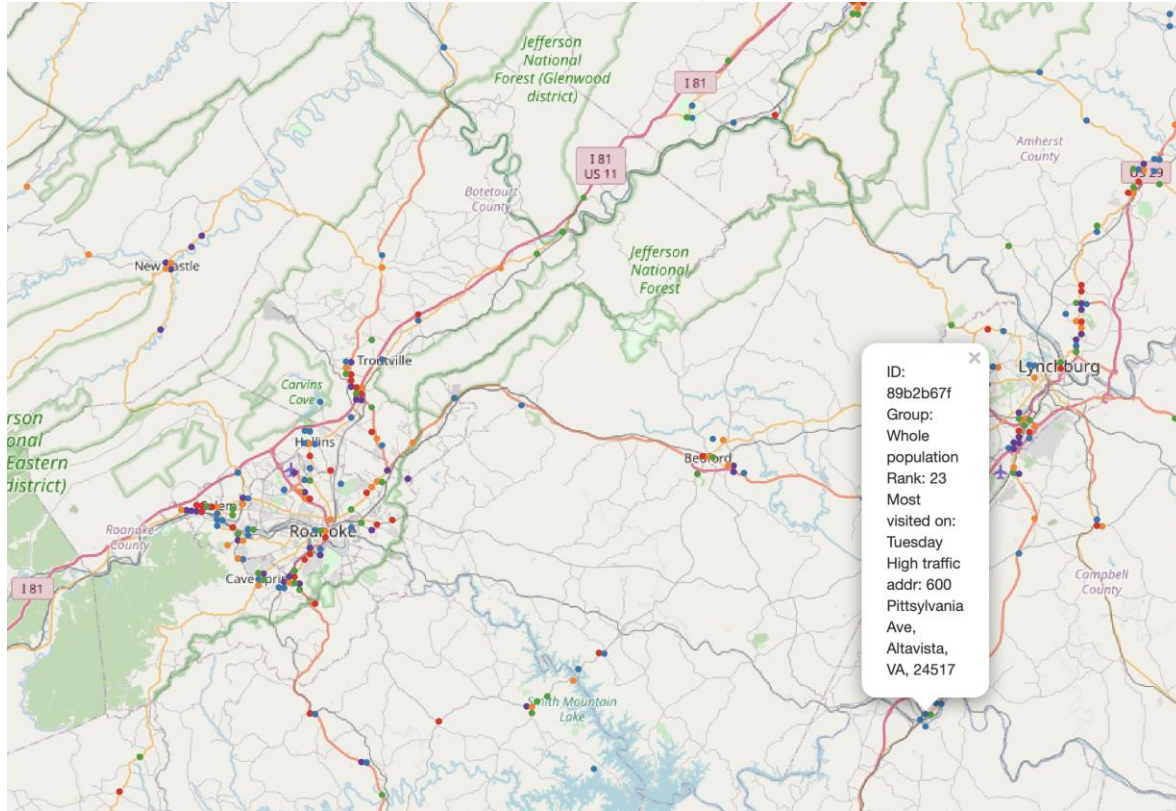
45% asymptomatic

To determine a confidence interval with a 95% chance of containing the true variant proportion (+/-10% of the prevalence), you need ~35 samples



# Data Recommended Mobile Vax Clinic Sites

## Detailed and Timely Locations



## Data Delivered and Disseminated to Locals

Provides a list of areas most visited by a given demographic group based on SafeGraph mobility data that links visits to specific sites and the home Census Block Group of the anonymized visitors

**Demographic Groups:** Black, Lantinx, Young Adults (20-40), Unvaccinated, and Whole Population

**Data Included:** Rank, Weight, most visited Day of Week, Highly Visited Address, and Lat-Long of area

**Goal:** Provide frequently visited locations based on populations and vaccination levels one desires to reach

**Example:** List of location in the Southside frequented by 20-40 year olds

# Key Takeaways

Projecting future cases precisely is impossible and unnecessary.

Even without perfect projections, we can confidently draw conclusions:

- **Case rates in Virginia have flattened with some minor growth in some areas**
- 63% of zip codes in Virginia (566 of 896 zips) had zero cases this past week; VA mean weekly incidence slightly up to 1.9/100K from 1.6/100K, US flat at 3.9/100K (from 4.2/100K)
- Vaccination rates continue to decline while measured acceptance among unvaccinated remains steady
- Projections show potential for growth, especially with variant Delta's increasing prevalence
- Recent updates:
  - Added Delta variant scenario as its growth becomes more predictable and expanded vaccination
  - Study scenarios: Fall resurgence and Fatigued control spike in summer
  - Limited waning of natural immunity included in fit and projections, also with seroprevalence update
- The situation continues to change. Models continue to be updated regularly.

# References

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NSSAC. PatchSim: Code for simulating the metapopulation SEIR model. <https://github.com/NSSAC/PatchSim>

Virginia Department of Health. COVID-19 in Virginia. <http://www.vdh.virginia.gov/coronavirus/>

Biocomplexity Institute. COVID-19 Surveillance Dashboard. <https://nssac.bii.virginia.edu/covid-19/dashboard/>

Google. COVID-19 community mobility reports. <https://www.google.com/covid19/mobility/>

Biocomplexity page for data and other resources related to COVID-19: <https://covid19.biocomplexity.virginia.edu/>

# Questions?

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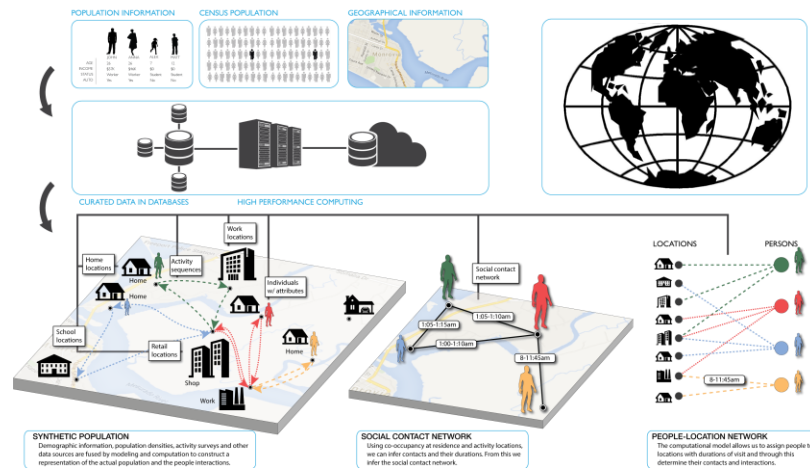


# Supplemental Slides

# Agent-based Model (ABM )

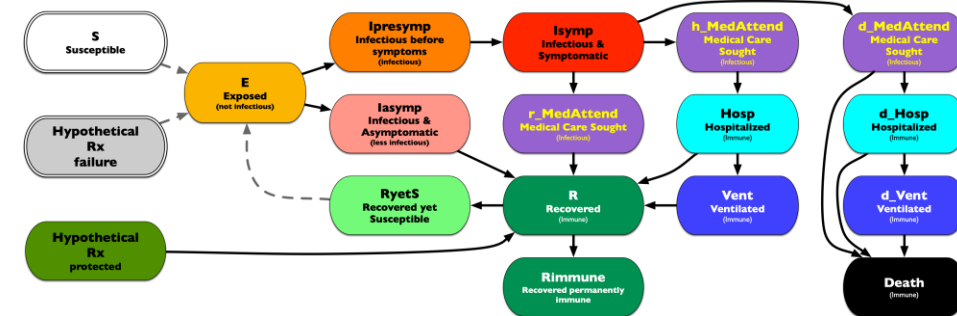
## EpiHiper: Distributed network-based stochastic disease transmission simulations

- Assess the impact on transmission under different conditions
- Assess the impacts of contact tracing



### Synthetic Population

- Census derived age and household structure
- Time-Use survey driven activities at appropriate locations



### Detailed Disease Course of COVID-19

- Literature based probabilities of outcomes with appropriate delays
- Varying levels of infectiousness
- Hypothetical treatments for future developments